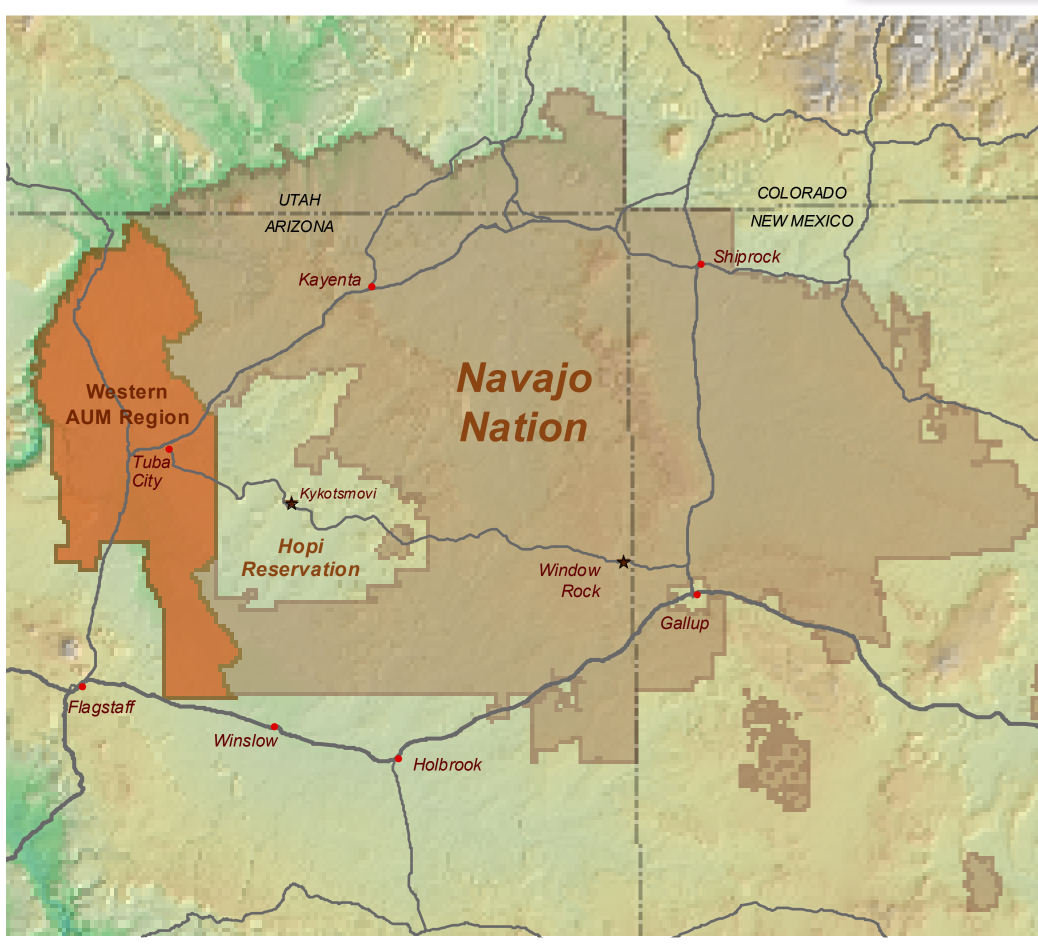
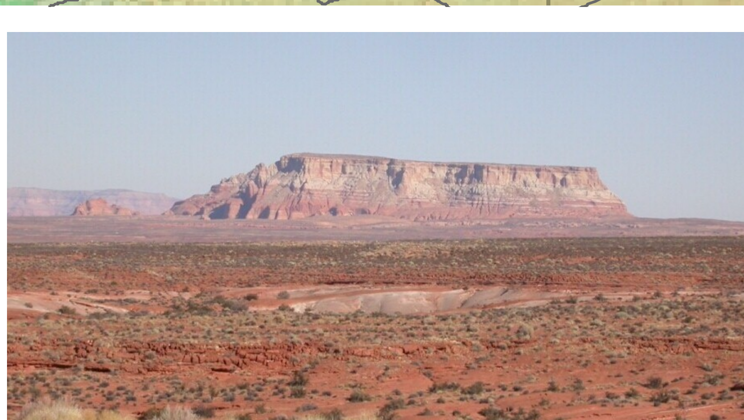
ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

WESTERN AUM REGION SCREENING ASSESSMENT REPORT

Bodaway/Gap, Cameron, Coalmine Canyon, Coppermine, LeChee, Leupp, and Tuba City



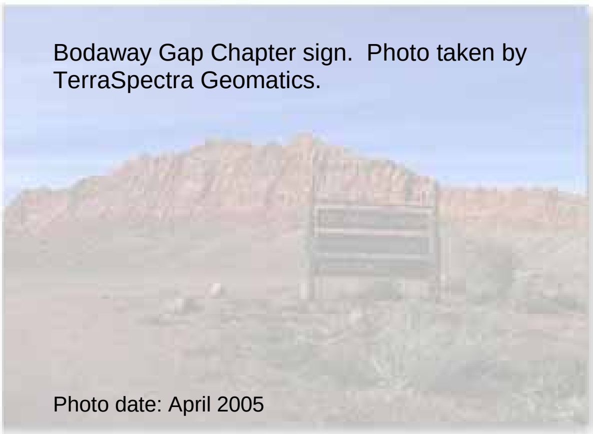


Navajo Nation
Environmental Protection Agency

U.S. Environmental
Protection Agency - Region 9

Navajo Abandoned
Mine Lands Reclamation Program

COVER PHOTOS

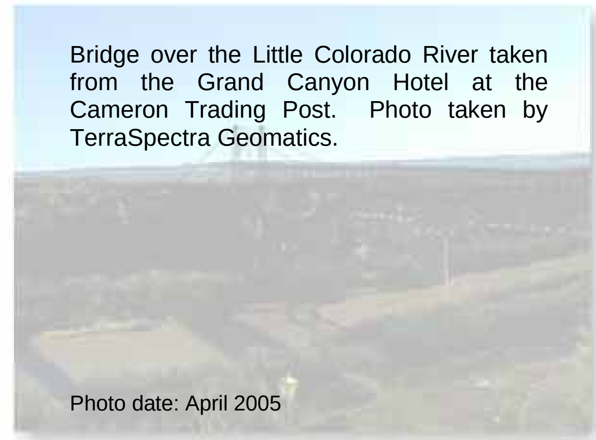


Bodaway Gap Chapter sign. Photo taken by TerraSpectra Geomatics.

Photo date: April 2005

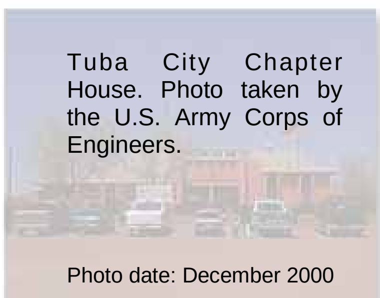
Yazzie 312 Open Pit Mine. Photo taken by the U.S. Army Corps of Engineers.

Photo date: July 1998



Bridge over the Little Colorado River taken from the Grand Canyon Hotel at the Cameron Trading Post. Photo taken by TerraSpectra Geomatics.

Photo date: April 2005



Tuba City Chapter House. Photo taken by the U.S. Army Corps of Engineers.

Photo date: December 2000

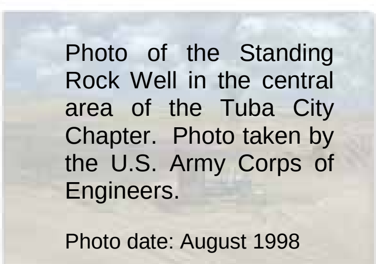
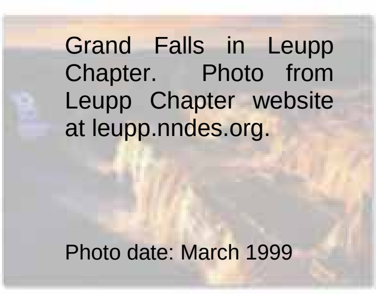


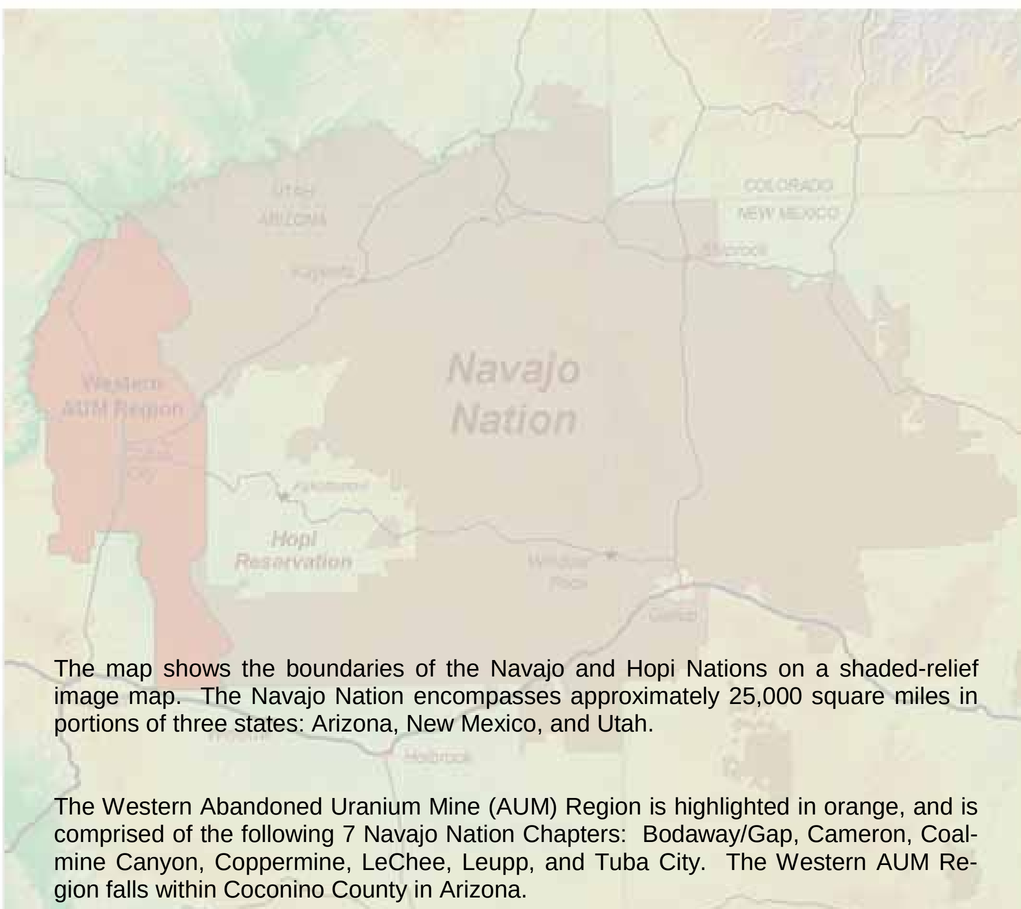
Photo of the Standing Rock Well in the central area of the Tuba City Chapter. Photo taken by the U.S. Army Corps of Engineers.

Photo date: August 1998



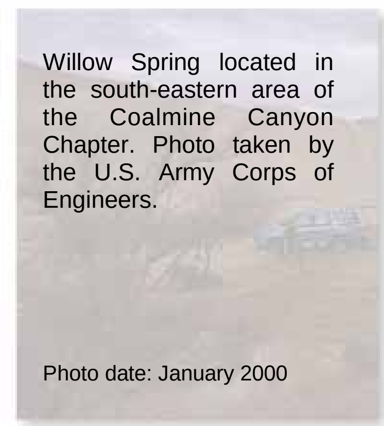
Grand Falls in Leupp Chapter. Photo from Leupp Chapter website at leupp.nndes.org.

Photo date: March 1999



The map shows the boundaries of the Navajo and Hopi Nations on a shaded-relief image map. The Navajo Nation encompasses approximately 25,000 square miles in portions of three states: Arizona, New Mexico, and Utah.

The Western Abandoned Uranium Mine (AUM) Region is highlighted in orange, and is comprised of the following 7 Navajo Nation Chapters: Bodaway/Gap, Cameron, Coalmine Canyon, Coppermine, LeChee, Leupp, and Tuba City. The Western AUM Region falls within Coconino County in Arizona.



Willow Spring located in the south-eastern area of the Coalmine Canyon Chapter. Photo taken by the U.S. Army Corps of Engineers.

Photo date: January 2000

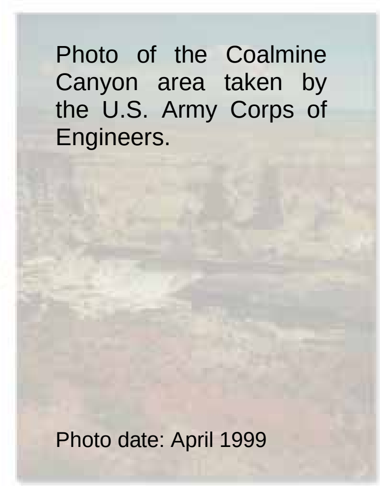
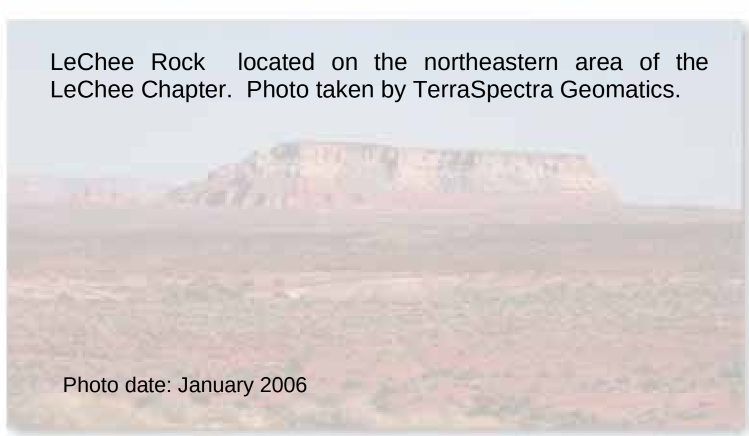


Photo of the Coalmine Canyon area taken by the U.S. Army Corps of Engineers.

Photo date: April 1999

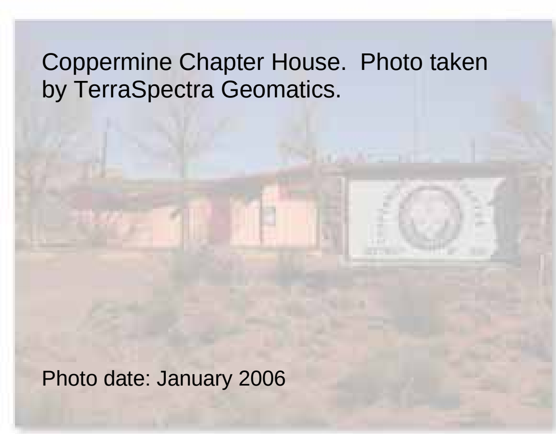
Welcome to LeChee Chapter sign. Photo taken by TerraSpectra Geomatics.

Photo date: January 2006



LeChee Rock located on the northeastern area of the LeChee Chapter. Photo taken by TerraSpectra Geomatics.

Photo date: January 2006



Coppermine Chapter House. Photo taken by TerraSpectra Geomatics.

Photo date: January 2006

We gratefully acknowledge William L. Chenoweth's significant contributions to this report.

Developed in Cooperation with:

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Project Manager: Stanley W. Edison

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ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

WESTERN AUM REGION SCREENING ASSESSMENT REPORT

NAVAJO NATION CHAPTERS INCLUDED
IN WESTERN AUM REGION:

Bodaway/Gap
Cameron
Coalmine Canyon
Coppermine
LeChee
Leupp
Tuba City

Coconino County, Arizona

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May 2006

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Western AUM Region Screening Assessment Report

CONTENTS

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Western AUM Region Screening Assessment Report

COMMUNITY INTRODUCTION

In April 2000, the Navajo Nation Environmental Protection Agency (NNEPA), the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP)[1] and the United States Environmental Protection Agency (EPA) Region 9 made a decision to map and screen all abandoned uranium mines on the Navajo Nation for possible remedial actions. In addition to their own data, the three agencies collected information from tribal, state, and federal agencies, including census, cultural, wildlife, and water resource agencies.

The Western AUM Region screening assessment that follows this introduction provides valuable information and maps of mine locations, the mine type, and how close the mines are to homes and water sources. If you have questions about the information or about our programs or the science, please feel free to contact any member of our team listed in the contact information provided (see MISSION STATEMENTS). After all the data is collected, tribal and federal agencies will use the information to determine appropriate assessments, including possible cleanup actions.

For the purposes of this introduction, “abandoned uranium mines” are uranium mines that have been deserted, are no longer being maintained, no further mining is intended, and the mine may pose a hazard. Based upon several chapter meetings, the following are frequently asked questions that the agencies have been asked in their outreach work. These questions are important to people who live in areas with abandoned uranium mines. These questions focus on the environment and health.

ENVIRONMENT

1. *What are the impacts of abandoned uranium mines to the water we drink (groundwater and surface water)?*

   Uranium is a common, naturally occurring radioactive material that is present in our environment and may be found in water, soil, rock formations, and air. If water is present in the ground next to rocks containing uranium, there will be a certain amount of uranium in the water. Uranium in water comes from different sources. Most of it comes from the water running over uranium bearing rocks and through the soil. Only a small amount comes from airborne dust that settles on water. In some cases, the uranium can be suspended in water, like mixing dirt to make muddy water. Human activities, such as mining, can move the uranium around and change the levels that you are exposed to.

2. *What are the impacts of abandoned uranium mines to soil?*

   Mining practices at abandoned uranium mines often disturbed the natural makeup of soils, thus making them less stable and more susceptible to erosion. Concentrated ore was brought to the surface and indirectly caused the spread of contaminated soils in staging areas. During the digging, the sandstone rock containing the ore was separated by hand, loaded into trucks and transported off-site for milling. Uranium was also spread by erosion and blowing dust and can be found concentrated at the waste piles and ore transfer stations. Soils disturbed by mining are also likely to support less vegetation or they may support a totally new species mix due to the changes in soil composition. Several of these locations on the Navajo Nation have been assessed to identify areas of concern.

3. *What are the impacts of abandoned uranium mines to air?*

   In the air, uranium exists as dust. Very small dust-like particles of uranium in the air fall out of the air onto surface water, plant surfaces, and soil either by themselves or when rain falls. The amount of uranium dust particles in air is usually very small, so it is not considered a significant concern for health impacts.

HEALTH

Uranium is found everywhere naturally in small amounts. We take uranium into our bodies through the food and water we ingest and from the air we breathe. Additionally, we are exposed to radiation from cosmic and natural sources on earth all the time. In a few places, there is more natural uranium in water than in food. People living in these areas take in more uranium from their drinking water than from their foods. When we breathe uranium dust, some of it is exhaled and some stays in our lungs. The size of the uranium dust particles and how easily they dissolve determines where in the body the uranium goes and how it leaves the body. Some of the uranium dust may gradually dissolve and go into the blood. The blood carries the uranium throughout the body and most of it leaves in your urine in a few days, but a little stays in your kidney and bones.

1. *How far should I live from an abandoned uranium mine, whether it is reclaimed or not?*

   Reclaimed abandoned uranium mines should pose little risk for health hazards because work has been done to make the physical mine area safe and stable. The soils were carefully surveyed with radiation detecting equipment to identify problem areas. The uranium-contaminated soils were buried and many steep areas were stabilized to prevent further movement of the uranium containing soils. Drainage patterns have been diverted away from reclaimed areas to reduce the leaching capability of surface water. Any unreclaimed abandoned uranium mines may pose some risk. The agencies strongly advise people to reduce their exposure to places where there are abandoned uranium mines or mine wastes. People who already live near a mine, or a community considering an area for future development, will want to ask specific questions about a particular mine site or waste pile to better understand the risks. These questions are based on radiation safety principles known as ALARA (As Low as Reasonably Achievable), and follow three basic principles that can be applied to reduce potential exposures to radiation: time, distance, and shielding. Questions could include the following: How long is the person exposed, including residential, farming and recreational activities (time)? How close is the person to the source of exposure while doing these activities (distance)? Is there something between the person and the source of exposure that can absorb some of the radiation (shielding)?

   In the Western AUM Region, the agencies looked at how close structures (e.g., homes, churches, businesses) were located to the mines to assess the potential for people to be exposed. This report serves as a tool for the agencies to discuss where cleanup decisions are needed, as well as how and who can address them.

[1] NAMLRP provided technical and review assistance to the project.

2. *What will happen if I drink water that contains small particles (dissolved) of uranium and heavy metals?*

   The Navajo Nation issued a health advisory in 2001 recommending people drink water from regulated safe drinking water sources such as Navajo Tribal Utility Authority (NTUA) and Indian Health Services (IHS) systems. These sources of water are sampled and tested routinely to ensure it is safe to drink. Water containing natural uranium is radioactive, but only to a weak extent. At high concentrations, uranium also has a toxic, chemical effect, and people have developed kidney disease drinking highly contaminated water for long periods. This is why the EPA has established standards for uranium in drinking water throughout the United States which are safe for long-term water use. As long as the levels in the drinking water are below these concentrations, the water is safe to drink. The uranium drinking water standard is 30 parts per billion. Please refer to the EPA website for the list of drinking water standards for other elements of concern, including arsenic and lead: *http://www.epa.gov/safewater/mcl.html* . For more information on the health effects of uranium, arsenic and lead, please refer to the Agency for Toxic Substances and Disease Registry website: *http://www.atsdr.cdc.gov/toxfaq-u.html#bookmark05*

   In the Western AUM Region, we looked at how close water sources (for example wells, developed springs, and stock tanks) were located to the abandoned uranium mines to assess the potential for people to be exposed. Please see Figures 6 through 12 for maps showing the locations of water sources and mines within the Western AUM Region.

3. *What are the effects of ingesting uranium that has been taken up by livestock*

   There is not enough research in this area, but it is advisable that livestock not graze on areas where abandoned uranium mines are located.

4. *What can people do to reduce the risk of exposure to uranium?*

   The most common and easiest things to do are the following:
   - Avoid abandoned uranium mines, waste piles, or mill tailings piles.
   - Do not collect any rocks from the vicinity of known uranium mines, waste ore piles, or transfer stations.
   - Do not use suspect rocks for building homes, foundations, root cellars, corrals, bread ovens, fireplaces, or any other structures.
   - If you have yellowish rocks or any rock you know that has come from a uranium mine area in your home or yard, call the Navajo Superfund Project Manager at 888-643-7692 or 928-871-6859 for additional information.
   - Do not drink from unregulated water sources such as windmills, stock tanks, and springs.

5. *Is it safe to wash dishes or laundry with contaminated water?*

   No, the agencies recommend using water from a regulated source such as NTUA and IHS systems.

   If you have questions about your drinking water quality, please contact NNEPA Public Water Supply at 928-871-7715. You can reach NTUA at 928-729-5721.

Radiation Exposure Compensation Act (RECA)

Where can I apply for Radiation Exposure Compensation Act (RECA) benefits?

The Uranium Office in Shiprock, New Mexico can provide application packets and pertinent information for miners, transporters, millers, and down winders.

Larry Martinez
Uranium Office
Post Office Box 1890
Shiprock, New Mexico 87420
Telephone: 505-368-1261 Fax: 505-368-1266

Uranium Office
Post Office Box 1079
Tuba City, Arizona 86045
Telephone: 928-283-3008 or
928-283-3009

Radiation Exposure Screening and Education Program (RESEP)

Where can I get screened for compensation requirements under the Radiation Exposure Screening and Education Program?

The following are screening facilities:

Shiprock Northern Indian Health Service
Post Office Box 160
Shiprock, New Mexico 87420
Telephone: 505-368-7032

RESEP Coordinator
Montezuma Creek Clinic
Post Office Box 130
Montezuma Creek, Utah 84534
Telephone: 435-651-3291

RESEP Coordinator
Lake Powell Medical Center
Post Office Box 1625
Page, Arizona 86040
Telephone: 928-645-8123, ext. 206

RESEP Coordinator
North Country Community Health Center
2301 N. 4th St, Suite 101
Flagstaff, Arizona 86003
Telephone: 928-779-7277

MISSION STATEMENTS

NAVAJO NATION ENVIRONMENTAL PROTECTION AGENCY

On April 21, 1995, the Navajo Nation Council established the Navajo Nation Environmental Protection Agency (NNEPA). NNEPA is an independent regulatory agency within the Executive Branch of the Navajo Nation Government with regulatory, monitoring, and enforcement authority over matters relating to the quality of the environment and over any person or entity doing business within, or otherwise affecting the environment of the Navajo Nation.

On May 22, 2001, the NNEPA received approval to amend the plans of operations for the Air & Toxics Department, the Surface and Ground Water Protection Department, the Waste Regulatory & Compliance Department (WRCD), and the Criminal Enforcement Department. The first three departments are responsible for the civil and administrative enforcement of Tribal environmental laws and regulations. Criminal environmental crimes are investigated by the Criminal Enforcement Department.

Each department consists of several programs that are responsible for program development, technical and enforcement development, conducting research, investigating and assessing environmental problems and concerns, monitoring cleanup and/or corrective actions, and providing technical assistance and training.

Funding for NNEPA is provided by Navajo Nation general funds, federal grants from the U.S. Environmental Protection Agency (EPA), the U.S. Department of Justice, and from fees that are collected under existing Tribal environmental laws.

The Navajo Superfund Program (NSP) is one of several programs within the WRCD. The NSP is funded by an EPA grant under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. Under CERCLA, NSP is responsible for conducting site assessments where hazardous substances may have been used by past development activities, such as uranium mining and milling activities that occurred in the Western AUM Region.

NSP has conducted assessments at several abandoned uranium mine sites. Activities related to the assessments included collecting samples of soil sediments and both surface and ground water. Other activities included conducting surveys using instruments to detect different types of radiation, conducting interviews of chapter officials and local residents, and reviewing U. S. Bureau of Indian Affairs (BIA) lease information to identify the companies that developed the mines. The information was submitted to the EPA for use in the federal Hazard Ranking System (HRS) to score each site and to determine the threat associated with actual or potential releases of hazardous substances. EPA uses the HRS to set priorities for further site evaluation and determine possible remedial action if the site is eligible for placement on the National Priorities List (NPL). The NPL identifies sites at which the EPA may conduct remedial response actions.

For further information about NNEPA or the Western AUM Screening Assessment Report you may contact the following:

Mr. Steven B. Etsitty, Executive Director
Navajo Nation Environmental Protection Agency
Post Office Box 339
Window Rock, Arizona 86515
Telephone: 928-871-7692

Ms. Arlene C. Luther, Environmental Department Manager
Waste Regulatory Compliance Department
Navajo Nation Environmental Protection Agency
Post Office Box 339
Window Rock, Arizona 86515
Telephone: 928-871-7993

Ms. Diane J. Malone, Program Manager
Navajo Superfund Program
Post Office Box 2946
Window Rock, Arizona 86515
Telephone: 928-871-6859

NAVAJO ABANDONED MINE LANDS RECLAMATION PROGRAM

The Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) is a program under the Navajo Nation Division of Natural Resources. The purpose of the program is to fulfill the requirements of Public Law 95-87 “Surface Mining Control and Reclamation Act (SMCRA) of 1977.” Title IV of Public Law 95-87 addresses abandoned mine reclamation.

Through SMCRA, reclamation funds for abandoned mine lands were set up to address land and water resources impacted by abandoned mines for which there were no responsible parties. Reclamation under this program can only be addressed to lands that have tribal trust status.

A trust fund was established in the U.S. Treasury as the Abandoned Mine Reclamation Fund to be administered by the Secretary of the Interior. All active coal mining operations deposit 35 cents per ton of coal produced into the fund, while underground mining operations deposit 15 cents per ton of coal produced. Fifty percent of the Abandoned Mine Lands Reclamation funds go to eligible tribes and states who can use it for administration, project development, and construction costs.

The NAMLRP was established in 1988 and since then they have been reclaiming abandoned coal and non-coal mine sites within the boundaries of the Navajo Nation.

After the establishment of the NAMLRP, the following tasks were completed in order to understand the mining scenario throughout the Navajo Nation. NAMLRP completed an inventory, prioritized the abandoned mine sites, and made a determination as to which sites would be reclaimed according to Office of Surface Mining criteria. Several factors were taken into consideration, such as the need to protect public health, environmental problems, and overall safety for employees.

For further information about NAMLRP, you may contact the following:

Main Office : Madeline Roanhorse, Department Manager III
Navajo Abandoned Mine Lands Reclamation Program
Post Office Box 1875
Window Rock, Arizona 86515
Telephone: 928-871-6982

Field Office : Rose Grey, Program Manager II
Navajo Abandoned Mine Lands Reclamation Program
Post Office Box 3605
Shiprock, New Mexico
Telephone: 505-368-1220

Field Office : Ray Tsingine, Program Manager II
Navajo Abandoned Mine Lands Reclamation Program
Post Office Box 730
Tuba City, Arizona 86045
Telephone: 928-283-3187

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

The mission of the U. S. Environmental Protection Agency (EPA) is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people. EPA employs 18,000 people across the country, including our headquarters offices in Washington, DC, ten regional offices, and more than a dozen laboratories. EPA conducts environmental science, research, education and assessment efforts. EPA develops and enforces regulations, provides financial assistance, performs environmental research, and cleanup of contaminated sites.

EPA's Region 9 covers the southwestern United States (Arizona, California, Nevada, and Hawaii) and it works with 147 federally recognized tribes. EPA Region 9 has a Memorandum of Understanding with the Navajo Nation to work with the NNEPA in a government to government relationship. In response to concerns raised by the Navajo Nation during a 1993 Congressional hearing, the EPA Region 9 Superfund Program initiated an investigation aimed at assessing human exposure to radiation and heavy metals from abandoned uranium mines. EPA conducted extensive field sampling of abandoned uranium mines, water sources, and homes during the 1990s. In 2002, EPA developed the Abandoned Uranium Mine Project Management Plan in partnership with the NNEPA to create a screening assessment mechanism, with close involvement by the NAMLRP.

The U.S. Army Corps of Engineers is producing a Geographic Information System (GIS) database and summary reports for EPA in support of AUM screening assessments on the Navajo Nation. The GIS database will identify the locations of all known uranium mines on the Navajo Nation and their proximity to structures, water sources, and surface water drainages. The reports will allow the project team to recommend Superfund removal actions or assessments to determine a site’s eligibility for Superfund removal actions and/or Superfund Site listing to the NNEPA. Based on the results of the mine screening study, EPA will consult with the Navajo Nation about the recommended follow-up investigations or cleanup responses requiring prompt attention. NNEPA, NAMLRP and EPA expect to complete the screening assessment phase by December 2006.

With respect to future work, EPA and NNEPA will coordinate closely with the NAMLRP to address directly or seek additional resources to address sites such as waste piles, unreclaimed mines, and mine contaminated water sources.

For further information about EPA or the Western AUM Region Screening Report, you may contact the following:

Andrew Bain, Remedial Project Manager (SFD-8-2)
U. S. Environmental Protection Agency
75 Hawthorne Street
San Francisco, California 94105
Telephone: 415-972-3167

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Western AUM Region Screening Assessment Report

PURPOSE

The purpose of the Abandoned Uranium Mines and the Navajo Nation Project (AUM Project) is to conduct assessments to identify radiation sources, potential exposures, and to recommend methods to reduce exposure from AUMs on the Navajo Nation. There are more than 1,000 AUM mine features (e.g., adits, pits, rim strips) located throughout the Navajo Nation. Potential long-term exposure risks can persist even after the surface reclamation of AUM sites is completed. Therefore, an assessment of potential impacts to humans and the environment from the abandoned mines is needed.

The goal of the current phase of the AUM Project is to perform screening assessments to prioritize Navajo AUM sites using existing, readily available data. The focus is to identify the areas with the highest apparent level of risk in order to recommend additional investigations by the appropriate Navajo or lead federal agency. Screening Assessment Reports and Geographic Information System (GIS) Data Packages will be developed for six regions of the Navajo Nation that experienced uranium mining. This Western AUM Region Screening Assessment Report is the second of these reports, and describes the resulting Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) derived screening assessment conducted for the Western AUM Region. A brief overview of the CERCLA process and a discussion of potential contaminants and exposure pathways related to AUMs is provided for background.

BACKGROUND

Widespread mining of uranium ore for Cold War weapons and nuclear energy production occurred on the Navajo Nation and throughout the Colorado Plateau. The Bureau of Indian Affairs (BIA) and the Navajo Nation negotiated mining leases with a number of private mining companies, who in turn processed the ore at their own facilities (mill sites) or sold the raw uranium ore to such facilities. Ultimately, the former United States Atomic Energy Commission (AEC) and its successor agency, the U.S. Department of Energy (DOE), acted as the sole market for all uranium ore.

It is probable that the mining activities led to dispersion of radioactive and heavy metal contaminated dusts, sediments, groundwater, and surface water to varying degrees, depending on site conditions, mining practices, and the amount and grade of material extracted. Since uranium is a naturally occurring element, the questions of how much dispersion or contamination occurred as a direct result of mining, who is at risk, and to what extent, are difficult to answer without a systematic review and analysis of all the AUM sites.

Congressional hearings about these concerns were conducted on November 4, 1993 (U.S. House of Representatives, 1993). During the hearings, the Navajo Nation presented testimony about the AUMs and requested assistance in determining if the mines posed a health risk to residents. The U.S. Environmental Protection Agency (EPA) presented testimony to describe its federal authority under CERCLA and how the EPA could assist the tribe. The DOE, the U.S. Department of Interior (DOI), the Navajo Nation Environmental Protection Agency (NNEPA), and the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) also participated in the hearings.

In response to the concerns raised by the Navajo Nation at the Congressional hearings, the EPA initiated the AUM Project in 1994. Under the authority of CERCLA, the EPA conducted field data collection efforts between 1994 and 2000 to determine the scope and impact of uranium mining on the Navajo Nation. These efforts were undertaken in cooperation with NNEPA, NAMLRP, and U.S. Army Corps of Engineers (USACE). Independently, NAMLRP has reclaimed a large quantity of AUMs using Surface Mining Control and Reclamation Act (SMCRA) funds. In addition, DOE and the Nuclear Regulatory Commission (NRC) have authority for investigating and addressing the former mill sites under the Uranium Mill Tailings Radiation Control Act (UMTRCA), a number of which are located in Navajo communities.

During the first phase of the AUM Project, EPA conducted extensive aerial radiological surveys, collected water samples, and surveyed homes to determine if they were constructed with radioactive materials from the mines. EPA prepared a draft Integrated Assessment for the King Tutt Mesa area (EPA, 1999). EPA released a Project Atlas in 2000, providing an overview of the AUM Project data collected from 1994 to 2000, including the water and aerial radiation survey data (EPA, 2000a).

In 2002, the Navajo Nation and EPA refocused the project approach, agreeing on the need to conduct a systematic review of existing data spanning the full spatial extent of the Navajo Nation to best address the CERCLA questions. NAMLRP provided EPA with uranium mine site locations, representing the most accurate readily available source of such data. A GIS database was developed, concentrating on locational data about all known AUMs on the Navajo Nation. The resulting preliminary analysis will aid the agencies making CERCLA decisions and help plan for future use by the Navajo Nation.

The risk of human and ecological exposure on the Navajo Nation occurs in the following three ways, which may present risk on the surface and subsurface: 1) Naturally occurring radioactive material (NORM), 2) the uranium milling activities, and 3) the AUM sites. CERCLA only addresses wastes resulting from man-made activities, such as mining and related waste piles. EPA has no authority under CERCLA with respect to naturally occurring ore. EPA is also excluded from addressing mill sites; DOE and NRC have the authority and responsibility for mill site reclamation under UMTRCA.

PROJECT APPROACH

This screening assessment was undertaken using existing data, selected indicators from EPA's Hazard Ranking System (HRS), and applying the analytical capabilities of a GIS. Key elements of this effort include identifying:

1. The location of the original sources (i.e., AUM)
2. The potential pathways for source exposures
3. The location of population indicators (structures) and water sources at risk for exposure

EPA's Superfund program uses the HRS to evaluate whether a site is serious enough to be listed on the National Priorities List (NPL). Because there are over 1,000 known AUM mine features on the Navajo Nation, EPA needed to screen and prioritize all sites before applying the CERCLA process shown in Figure 1. EPA decided to use the geographic measures from the HRS to develop a basic screening model for the AUMs. This screening model includes the location of all known AUM sites as potential sources of exposure. Radiation and toxic metals that are released from an AUM site can travel through the air, through the soils, and through surface and groundwater. This model includes those pathways of potential contamination, and then evaluates the presence of structures as an indicator of population at potential risk to exposure.

The EPA project team created an HRS-derived model to compare the individual AUM sites by distance from the human receptors. This report presents the results from the model in data tables and maps that were designed to identify and prioritize the AUM sites that might pose the highest threat to their surrounding communities.

The results in this report were not generated using a complete HRS model, nor does the screening assessment specify NPL site candidates. Based on results from this broad-based screening process, the EPA, NNEPA and NAMLRP will discuss next steps. One of the possible results of the analysis in this report might be to conduct a Preliminary Assessment (PA) or Site Inspection (SI) at any specific sites identified as a priority via the scoring criteria and Navajo knowledge about the setting. Other decisions might entail referrals for EPA removal actions, referrals to other agencies, or a determination that no further action is necessary.

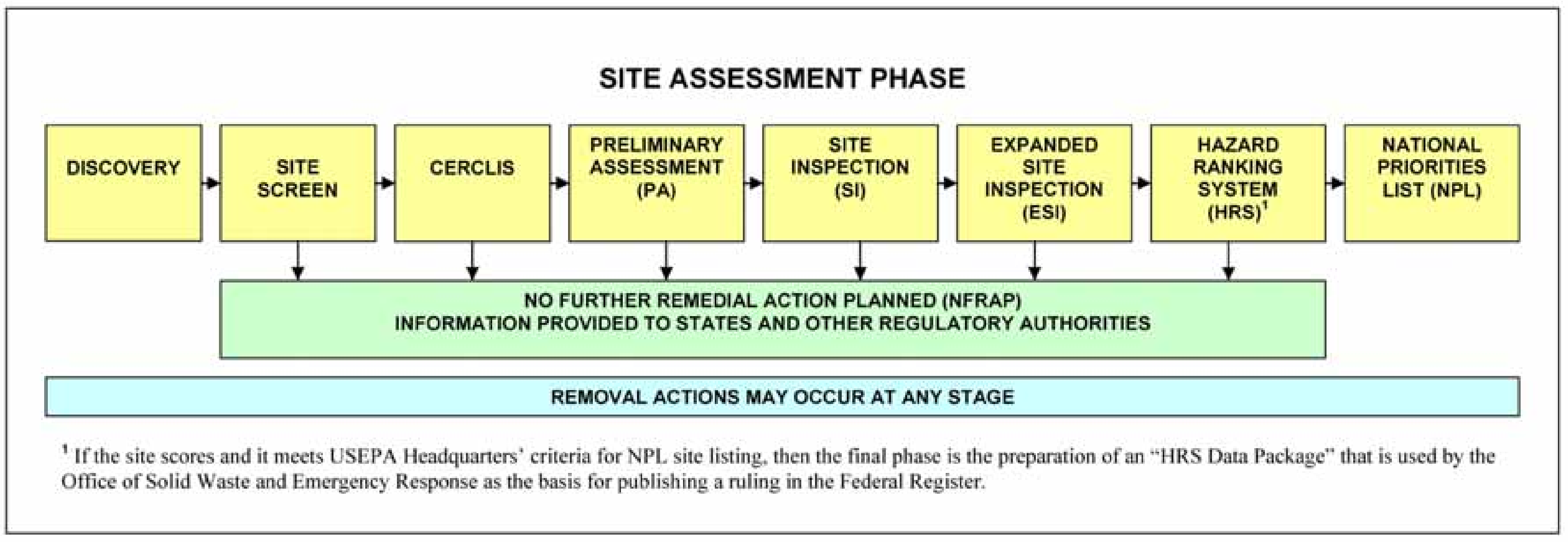


Figure 1. Superfund Process (modified after EPA, 1991).

The current phase of the AUM Project is limited to collecting existing and readily available data that can be used to: 1) identify potential radiation sources (AUMs), 2) screen for potential exposures, and 3) recommend follow-up actions. Table 1 provides the possible release mechanisms, pathways, exposure routes, and human and ecological receptors (targets) associated with AUMs.

PRIMARY SOURCES	RELEASE MECHANISM	PATHWAYS	EXPOSURE ROUTE	RECEPTOR		
				Area Resident	Livestock and Terrestrial Wildlife	Aquatic Wildlife
Uranium Mines and Natural Ore Bodies	Infiltration / Percolation	Ground Water	Direct Contact	✔	✔	✔
	Storm water Runoff	Surface Water and Sediments	Direct Contact	✔	✔	✔
	Particles/Dust	Soil Exposure	Inhalation	✔	✔	
			Direct Contact	✔	✔	
	Particles/Dust	Air	Inhalation	✔	✔	
			Direct Contact	✔	✔	

Table 1. Possible pathways, exposure routes, and human and ecological receptors (after EPA, 1991).

CONTAMINANTS AND EXPOSURE PATHWAYS

Although exposure to uranium in natural settings may be limited, mining activities often result in increased exposure risks. This includes both direct and indirect exposures that can occur via multiple pathways. Mining activities disturb mineralization that can affect exposures. Activities such as removing overburden, tunneling, and transporting ore can expose previously protected mineral deposits to accelerated oxidation and increase their mobility through the environment. These activities can also change groundwater and surface water flow, which can lead to the release of hazardous materials into the environment (EPA, 2000b).

Radioactive decay of the parent Uranium^{238} material produces a series of new elements and radiation, including radium and radon, alpha and beta particles, and gamma radiation. Because of the slow rate of decay, the total amount of natural uranium in the earth stays almost the same, but it can be moved from place to place through natural processes or by human activities. When rocks are eroded by water or wind, uranium minerals become a part of the soil. When it rains, the soil containing uranium minerals can be transported via leached material and deposited into rivers and lakes. Mining, milling, and other human activities can also move uranium around natural environments. Uranium ore concentrations and associated radioactivity varies widely at mining areas and geological formations across the Navajo Nation. Other potential contaminants of concern include arsenic and lead. EPA is evaluating the likelihood for offsite migration of contaminants due to historic mining activities, but not the natural occurrences (EPA, 2004).

WESTERN AUM REGION

The Western AUM Region was an important center of uranium mining on the Navajo Nation. The Western AUM Region is located in the western edge of the Navajo Nation, and is contained within Coconino County, Arizona. Figure 2 shows the location of the 7 chapters that comprise the Western AUM Region within the Navajo Nation: Bodaway/Gap, Cameron, Coalmine Canyon, Coppermine, LeChee, Leupp, and Tuba City.

The Western AUM Region covers approximately 4,028 square miles (2,578,312 acres) in the Painted Desert region of the Navajo Nation. The region is generally sparsely populated. The 2000 Census estimated the total resident population for the entire region at 15,676. Appendix A - Structures (page A-1) describes the general physical and population characteristics for each of the chapters comprising the Western AUM Region.

Uranium was mined in the Western AUM Region between 1951 and 1963. Chenoweth (1993) reported that there were 100 productive uranium-vanadium mines in the region, with 96 located on or within 1 mile of the Navajo Nation. In the Western AUM Region and within the Navajo Nation boundary, the Hosteen Nez mine was the only AUM with reported production that could not be accurately located and, therefore, was not included in the GIS dataset. It is generally believed to be located on the Ward Terrace at the foot of the Moenkopi Plateau. Twelve (12) AUMs with no production history, but with evidence of surface disturbance (e.g., trenches) and located within a mining claim were mapped. One (1) prospect (CAM061) was mapped by NAMLRP, but could not be associated with a mine name. A total of 108 AUMs were mapped in the Western AUM Region.

METHODOLOGY

The methodology followed these general steps to develop this Western AUM Region Screening Assessment Report:

- Develop a CERCLA HRS-derived model to assess and compare AUM priorities on the Navajo Nation
- Acquire data inputs for the HRS model and automate into a GIS database
- Apply the HRS screening criteria using GIS analysis tools
- Generate a scoring list for each pathway and a composite scoring list

HRS-DERIVED MODEL

The EPA Superfund Site Assessment and Technical Support Team selected a subset of HRS criteria to develop screening scores for the AUMs. The purpose of this analytical model is to prioritize Navajo AUM sites using readily available data. The level of detail in this study is not as robust as required for remedy decision making, since the purpose of the screening model is not to determine actual risks, but rather to identify priority areas for future investigation. The EPA team considered probable Navajo exposure pathways as the basis for the model. The large area involved in the assessment falls beyond the normal scope for HRS, so a custom model was developed to best fit these unique circumstances.

Due to the unique nature of the task, the EPA team considered the probable Navajo exposure pathways and used 40 CFR 300, Federal Register Notice, HRS Final Rule, December 1990 (EPA, 1990) as the basis for the HRS-derived model. Given the EPA's experience collecting available and pertinent Navajo Nation environmental data and the large land area under consideration, the EPA decided to conservatively address all known release points (i.e., uranium mines, mine-related features, and waste piles), all known drainages downstream from AUMs, all known water wells (domestic, agricultural, and municipal), and all structures. However, sensitive environments, such as endangered species, wetlands, and cultural data, were not readily available with enough locational specificity (compatible with GIS format) to input into the model. The inclusion of HRS criteria for sensitive environments would be recommended during future site-specific characterization activities, where the Navajo Nation would also be able to protect sensitive information with internal controls.

Consideration was given to the general fate and transport of radionuclides, as well as probable Navajo Nation exposure assessment scenarios. For example, the scenario of a rural homestead adjacent to an unfenced AUM site where the residents spend considerable waking hours outdoors with access to a nearby surface water source was considered. As a conservative assumption, it was presumed that all water sources may be used for human consumption and that uranium ore is mobile in dissolved media. For the two water pathways, a simple numeric progression was chosen. A higher bias was used in weighting the soil and air pathway for close proximity (within 200 feet) due to the rural, agrarian lifestyle of the residents. A lower bias was used in weighting the soil and air pathway for more distant proximity (>200 feet) due to strong winds associated with dispersion effects and the difficulty in attributing sources. The HRS-derived model developed for the AUM Project for each of the pathways is listed below.

Air Pathway – 200 feet, 1,320 feet (1/4 mile), and 1 mile.

- For structures within 200 feet of an AUM site, assign 100 points per structure,
- For structures that exist between 200 feet and 1,320 feet, assign 25 points per structure,
- For structures that exist between 1,320 feet and 1 mile, assign 10 points per structure, and
- For structures beyond 1 mile, assign 0 points.

Soil Exposure - 200 feet, 1,320 feet, and 1 mile.

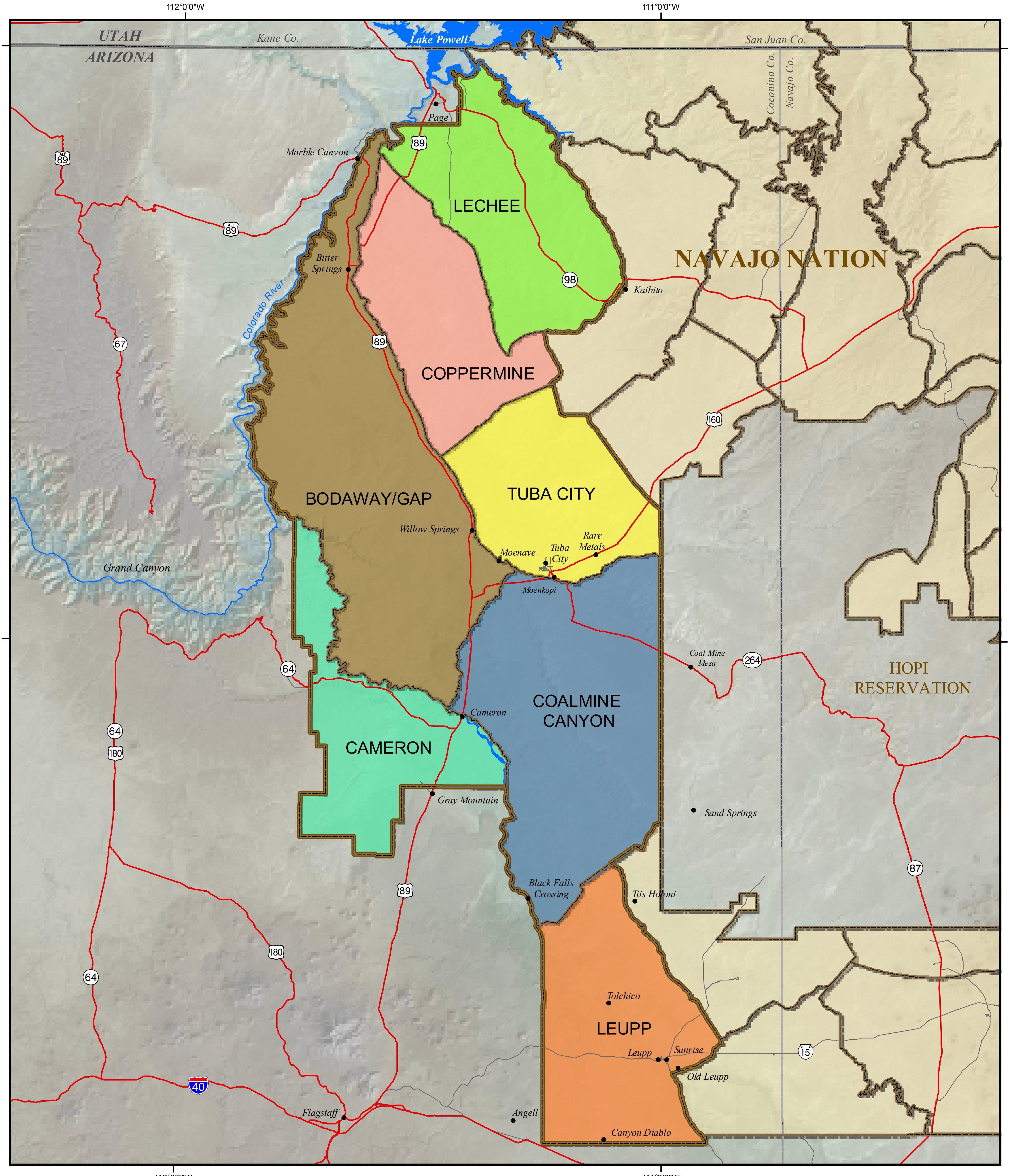
- For structures within 200 feet of an AUM site, assign 100 points per structure,
- For structures that exist between 200 feet and 1,320 feet, assign 25 points per structure,
- For structures that exist between 1,320 feet and 1 mile, assign 10 points per structure, and
- For structures beyond 1 mile, assign 0 points.

Groundwater Pathway - 1,320 feet, 1 mile, and 4 miles.

- For wells within 1,320 feet of an AUM site, assign 100 points per well,
- For wells that exist between 1,320 feet and 1 mile, assign 50 points per well,
- For wells that exist between 1 mile and 4 miles, assign 10 points per well, and
- For wells beyond 4 miles, assign 0 points.

Surface Water Pathway - 1 mile, 4 miles, and 15 miles.

- For perennial or intermittent surface water within one mile of an AUM site, assign 100 points,
- For perennial or intermittent surface water that exist between 1 mile and 4 miles, assign 50 points,
- For perennial or intermittent surface water that exists between 4 miles and within 15 miles, assign 10 points,
- For perennial or intermittent surface water beyond 15 miles, assign 0 points.



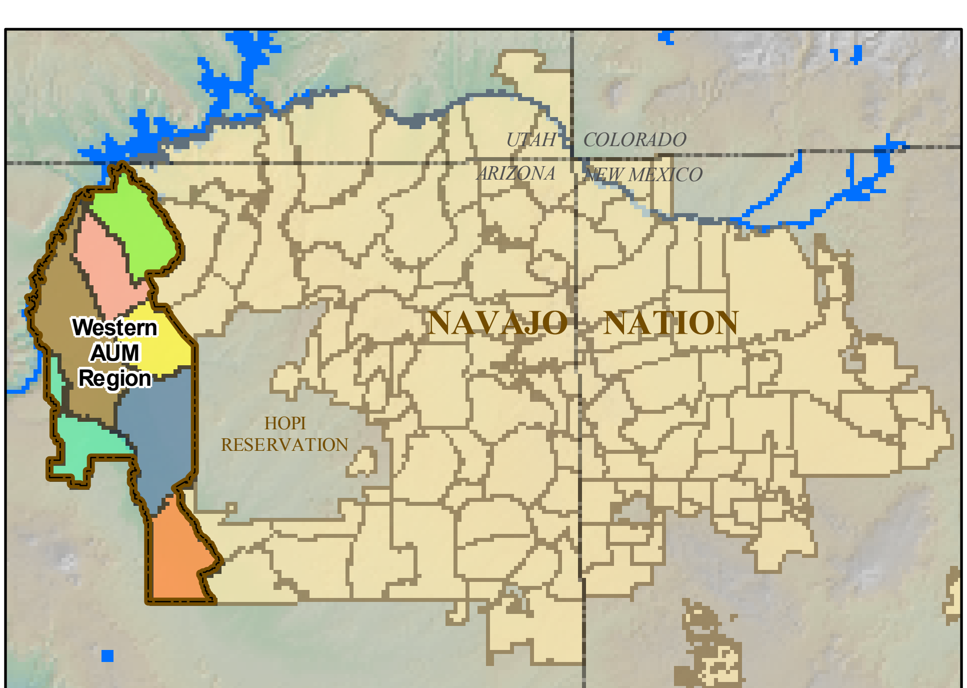


Figure 2. Western AUM Region Location on the Navajo Nation.

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Western AUM Region Screening Assessment Report

WESTERN AUM REGION

0 20 Miles

Map Scale 1:750,000

Legend

- Western AUM Region
- Chapter
- Highway
- Paved Road

DATA

The following data were identified as required to perform the HRS-derived scoring algorithm for the AUM Project:

AUM sites - Locations for the potential radioactive material sources (AUMs) were obtained from several sources, including: NAMLRP Reclamation Project Area boundaries, several uranium mining history reports by William L. Chenoweth, Navajo Tribal Mining Department Claim Maps, Scarborough (1981), U.S. Department of Energy aerial radiation surveys funded by EPA Region 9, U.S. Geological Survey (USGS) digital orthophoto quarter quadrangles (DOQQ) , and USGS 7.5' topographic maps scanned as digital raster graphic (DRG) files. AUM boundary polygons were generated for each of the identified AUMs and unreclaimed mine features. These polygons were used to represent the locations and surface extents of AUMs.

Structures - Structures are buildings that are residences or some other type of building where people may live, work, or gather. Locations of structures within 1 mile of AUMs were interpreted from DOQQs, USGS 7.5' topographic maps, and utility meter locations. Structures are the target for the air and soil pathways.

Wells - A wells dataset was acquired from the Navajo Water Resources Department and augmented using data from the Arizona Department of Water Resources, National Hydrography Database, Geographic Names Information System, U.S. Army Corps of Engineers water sample locations, USGS Ground-water Site Investigations Database, and USGS DRGs and DOQQs. Wells were used as the target for the ground water pathway.

Drainages - The USGS/EPA National Hydrography Dataset (NHD), along with DOQQs and DRGS were used to identify perennial and intermittent drainages downstream from AUMs.

Appendix A presents descriptions of the data sources, methods for data collection and automation into the GIS database, uses of the data, and data limitations. Appendix A also provides examples of map products that were developed from the GIS datasets.

RESULTS

This section presents the results of the HRS-derived screening model for AUM sites located within the Western AUM Region. As previously stated, these scores are not intended to indicate actual risk, but will be used to assist with establishing priorities for future investigations.

A summary table for the total groundwater pathway scores for each AUM and a summary table for the soil pathway and air pathway scores for each AUM were generated and are presented as Table 2 and Table 3, respectively. A separate summary table for the surface water pathway was not prepared, as explained below. The pathway summary tables include a MAP-ID, which is an arbitrary number to facilitate map labeling and is generally assigned so that MAP-ID increases from north to south and west to east. The MAP-ID numbers are unique to this report and do not correspond with MAP-ID numbers used in previous screening assessment reports. The tables include the name of the Chapter the AUM is located within; when the Chapter field is blank, the AUM is off the Navajo Nation but within 1 mile of the border. Each AUM was assigned a mine name or identifier using the following naming hierarchy: the mine or claim name (if available), or the NAMLRP reclamation project number, or finally, the NAMLRP point mine feature number. The groundwater pathway summary table presents the counts of wells that fall within the 1/4 mile, 1 mile, and 4 mile buffers and the total number of wells within 4 miles of each AUM. The scores for each buffer zone were tabulated and presented for each AUM in Table 2.

The soil and air pathway summary table presents the counts of structures that fall within the 200 foot, 1/4 mile, and 1 mile buffers and the total number of structures within 1 mile of each AUM. The scores for each buffer zone are tabulated and presented for each AUM. Since the air and soil pathway criteria are the same, the total score results for the soil pathway and air pathway are both shown in Table 3.

A summary table entitled "Combined Pathway Score" (Table 4) sums the total scores of each pathway for each AUM site to establish total scores. Maps showing the locations of the scored AUMs are presented at the end of this section.

SURFACE WATER PATHWAY

Water erosion is the process by which soil particles are detached and transported from their original location. Sedimentation is the by-product of erosion, whereby eroded particles are deposited at a location different from their origin. Erosion is a concern for AUMs because of the mine wastes. Major sources of erosion and sediment loadings at mining sites include waste rock and overburden piles, haul and access roads, exploration areas, and reclamation areas. Hazardous constituents (e.g., radionuclides and metals) associated with discharges from mining operations may be found at elevated levels in sediments (EPA, 2000b).

Evaluation of the surface water pathway using the modified HRS required the location of the AUM sites and distance to perennial and intermittent streams or drainages. The HRS criteria used to evaluate the surface water pathway were:

- For perennial or intermittent surface water within one mile of an AUM site, assign 100 points,
- For perennial or intermittent surface water between 1 mile and 4 miles, assign 50 points,
- For perennial or intermittent surface water between 4 miles and 15 miles, assign 10 points,
- If no perennial or intermittent surface water exists within 15 miles, assign 0 points.

All but two of the AUM sites within the Western AUM Region were located within 1 mile of a downstream intermittent stream or drainage (see Figure 3) and scored 160 (score = 100+50+10). Evans Huskon No. 35 (MAP-ID #79) and Cam061 (MAP-ID #80) are the two AUMs that scored 0. They are adjacent and are located in a relatively flat terrain with no clear downstream drainage channels (see Figure 11). A separate table was not developed for the Surface Water Pathway score results, but the total surface water scores are shown in Table 4 "Combined Pathway Scores".

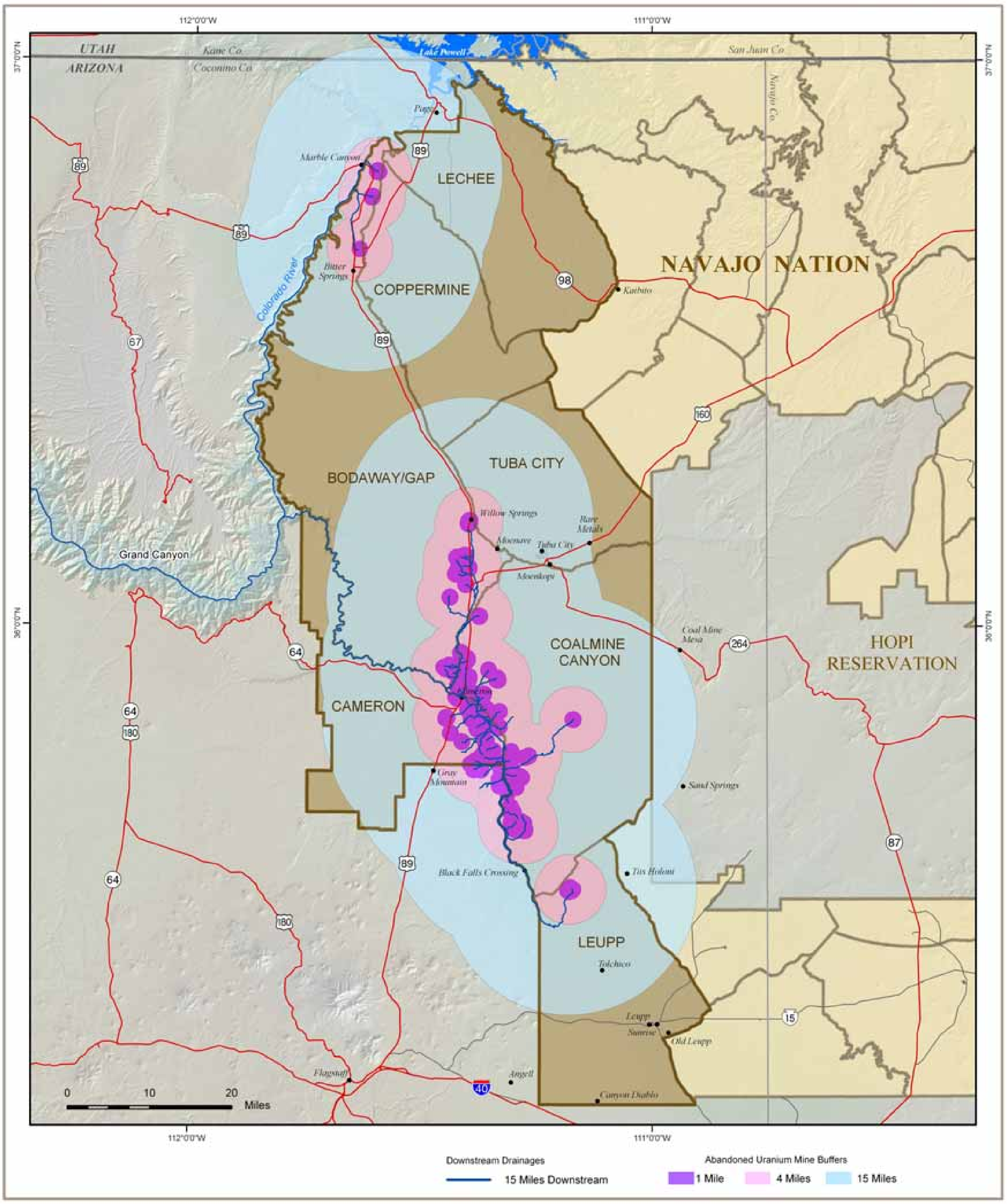


Figure 3. Surface Water Drainages Downstream from AUM Sites.

GROUNDWATER PATHWAY

Mining operations can affect groundwater quality in several ways. The most obvious occurs in underground workings, which can provide a direct conduit to aquifers. Groundwater quality is also affected when waters infiltrate through surface materials (e.g., mine debris piles) into groundwater. Contamination can also occur when there is a hydraulic connection between surface water and groundwater. Any of these situations can cause elevated contaminant levels in groundwater. In addition, contaminated groundwater may discharge to surface water down-gradient of the AUM site as contributions to base flow in a stream channel or spring (EPA, 2000b).

Evaluation of the groundwater pathway using the HRS-derived criteria required the location of the AUM sites and distance to wells (including developed springs). For the groundwater pathway, the mapped surface extents of the AUMs were used to generate the buffers. The HRS criteria used to evaluate the groundwater pathway were:

- For wells within 1,320 feet of an AUM site, assign 100 points per well,
- For wells between 1,320 feet and 1 mile, assign 50 points per well,
- For wells between 1 mile and 4 miles, assign 10 points per well, and
- If no well exists within 4 miles, assign 0 points.

Results for the groundwater pathway assessment are shown in Table 2. The table was sorted by MAP-ID number. The highest groundwater pathway score is 550 and is located at A & B No. 3 in the Cameron Chapter (MAP-ID #39). The total groundwater pathway score for this site is comprised of 0 wells within 1/4 mile of the AUM, 8 wells in the 1/4 mile to 1 mile buffer, and 15 wells in the 1 mile to 4 mile buffer.

Table 2. Groundwater Pathway Score.

MAP-ID	Chapter	Mine Name / Identifier Name	1/4 Mile Wells Count	1 Mile Wells Count	4 Mile Wells Count	Total Wells Count	1/4 Mile Score	1 Mile Score	4 Mile Score	Total Groundwater Score
1	Bodaway/Gap	Jimmie Boone A & B	0	0	3	3	0	0	30	30
2	Bodaway/Gap	Tommy	0	1	0	1	0	50	0	50
3	Bodaway/Gap	June	0	1	0	1	0	50	0	50
4	Bodaway/Gap	Thomas No. 1	0	3	4	7	0	150	40	190
5	Bodaway/Gap	Martin Johnson No. 4	1	0	1	2	100	0	10	110
6	Bodaway/Gap	Earl Huskon No. 1	0	0	2	2	0	0	20	20
7	Bodaway/Gap	Max Huskon No. 5	0	0	3	3	0	0	30	30
8	Bodaway/Gap	Paul Huskie No. 21	0	0	3	3	0	0	30	30
9	Bodaway/Gap	Earl Huskon No. 3	0	0	3	3	0	0	30	30
10	Bodaway/Gap	A & B No. 5	0	0	2	2	0	0	20	20
11	Bodaway/Gap	Max Huskon No. 1	0	0	2	2	0	0	20	20
12	Bodaway/Gap	Henry Sloan No. 1	0	0	3	3	0	0	30	30
13	Bodaway/Gap	Henry Sloan No. 1	0	0	2	2	0	0	20	20
14	Bodaway/Gap	Charles Huskon No. 7 (MP-357)	0	0	2	2	0	0	20	20
15	Bodaway/Gap	A & B No. 13	0	1	2	3	0	50	20	70
16	Bodaway/Gap	A & B No. 7	0	0	4	4	0	0	40	40
17	Coalmine Canyon	Charles Huskon No. 5	0	0	4	4	0	0	40	40
18	Coalmine Canyon	Charles Huskon No. 6	0	0	4	4	0	0	40	40
19	Coalmine Canyon	Lemuel Littleman No. 7	0	1	3	4	0	50	30	80
20	Coalmine Canyon	Jeepster No. 1	0	1	3	4	0	50	30	80
21	Bodaway/Gap	Montezuma No. 7C	0	0	3	3	0	0	30	30
22	Bodaway/Gap	Montezuma No. 7B	0	0	3	3	0	0	30	30
23	Bodaway/Gap	Montezuma No. 7B	0	0	9	9	0	0	90	90
24	Bodaway/Gap	Montezuma No. 7A	0	0	11	11	0	0	110	110
25	Bodaway/Gap	Montezuma No. 2	0	0	11	11	0	0	110	110
26	Bodaway/Gap	Montezuma No. 2	0	0	11	11	0	0	110	110
27	Bodaway/Gap	Montezuma No. 2	0	0	11	11	0	0	110	110
28	Coalmine Canyon	Casey No. 3	0	0	11	11	0	0	110	110
29	Coalmine Canyon	Jack Daniels No. 3	0	0	5	5	0	0	50	50
30	Coalmine Canyon	Kachina No. 6	0	1	12	13	0	50	120	170
31	Coalmine Canyon	Charles Huskon No. 19	0	1	12	13	0	50	120	170
32	Coalmine Canyon	Charles Huskon No. 19	0	2	12	14	0	100	120	220
33	Coalmine Canyon	Jack Daniels No. 5	1	1	13	15	100	50	130	280
34	Coalmine Canyon	Jack Daniels No. 1	0	2	13	15	0	100	130	230
35	Coalmine Canyon	Jack Daniels No. 4	1	1	15	17	100	50	150	300
36	Coalmine Canyon	Evans Huskon No. 34	0	0	6	6	0	0	60	60
37	Coalmine Canyon	Charles Huskon No. 20	0	0	6	6	0	0	60	60
38	Coalmine Canyon	Charles Huskon No. 12	0	1	16	17	0	50	160	210
39	Cameron	A & B No. 3	0	8	15	23	0	400	150	550
40	Coalmine Canyon	Max Johnson No. 1	0	2	18	20	0	100	180	280
41	Coalmine Canyon	Charles Huskon No. 1	0	3	17	20	0	150	170	320
42	Coalmine Canyon	Max Johnson No. 10	0	3	17	20	0	150	170	320
43	Coalmine Canyon	Lemuel Littleman No. 2	0	0	18	18	0	0	180	180
44	Coalmine Canyon	Harvey Begay No. 1	0	0	16	16	0	0	160	160
45	Coalmine Canyon	Max Johnson No. 9	0	2	16	18	0	100	160	260
46	Coalmine Canyon	Elwood Canyon No. 1	0	1	16	17	0	50	160	210
47	Coalmine Canyon	Alyce Tolino No. 1 & 3	0	2	16	18	0	100	160	260
48	Coalmine Canyon	Evans Huskon No. 2	0	2	16	18	0	100	160	260
49	Coalmine Canyon	Yazzie No. 101	0	2	15	17	0	100	150	250
50	Coalmine Canyon	Yazzie No. 312	0	2	16	18	0	100	160	260
51	Coalmine Canyon	Boyd Tisi No. 2	1	2	14	17	100	100	140	340
52	Coalmine Canyon	Juan Horse No. 3	1	2	14	17	100	100	140	340
53	Cameron	Lemuel Littleman No. 3	0	0	24	24	0	0	240	240
54	Coalmine Canyon	Juan Horse No. 4	0	2	15	17	0	100	150	250
55	Coalmine Canyon	Pat Lynch	0	0	6	6	0	0	60	60
56	Cameron	A & B No. 2	0	5	17	22	0	250	170	420
57	Cameron	Charles Huskon No. 14	0	1	20	21	0	50	200	250
58	Cameron	Harry Walker No. 19	0	0	19	19	0	0	190	190
59	Cameron	Montezuma No. 1	0	1	18	19	0	50	180	230
60	Coalmine Canyon	Manuel Denetsone No. 2	1	1	6	8	100	50	60	210
61	Coalmine Canyon	Jefferson Canyon No. 1	0	2	4	6	0	100	40	140
62	Cameron	Charles Huskon No. 3	0	0	11	11	0	0	110	110
63	Cameron	Charles Huskon No. 3	0	0	8	8	0	0	80	80
64	Cameron	Charles Huskon No. 3	0	0	9	9	0	0	90	90
65	Cameron	Charles Huskon No. 3	0	1	6	7	0	50	60	110
66	Coalmine Canyon	Jack Huskon No. 3	0	0	6	6	0	0	60	60
67	Cameron	Black Hair No.4	0	1	13	14	0	50	130	180
68	Cameron	Paul Huskie No. 20	0	0	7	7	0	0	70	70
69	Cameron	Huskon No. 7	0	0	7	7	0	0	70	70
70	Cameron	Yazzie No. 102	0	0	7	7	0	0	70	70
71	Coalmine Canyon	Yellow Jeep No. 7A and 7B	0	0	1	1	0	0	10	10
72	Cameron	Yazzie No. 105	0	0	4	4	0	0	40	40
73	Cameron	Charles Huskon No. 10	0	0	6	6	0	0	60	60
74	Cameron	Charles Huskon No. 10	0	0	6	6	0	0	60	60
75	Coalmine Canyon	Lloyd House	0	0	1	1	0	0	10	10
76	Cameron	Charles Huskon No. 8	0	0	5	5	0	0	50	50
77	Cameron	Charles Huskon No. 8	0	1	4	5	0	50	40	90
78	Cameron	Boyd Tisi No. 1	0	1	4	5	0	50	40	90
79	Coalmine Canyon	Evans Huskon No. 35	0	0	1	1	0	0	10	10
80	Coalmine Canyon	Cam061	0	0	1	1	0	0	10	10
81	Coalmine Canyon	Mel Gardner	0	0	2	2	0	0	20	20
82	Coalmine Canyon	Ryan No. 1	0	0	2	2	0	0	20	20
83	Cameron	Taylor Reid No. 2	0	2	4	6	0	100	40	140
84	Cameron	Taylor Reid No. 3	0	1	6	7	0	50	60	110
85		Section 1 Lease	0	1	5	6	0	50	50	100
86		Section 1 Lease	0	1	6	7	0	50	60	110
87		Ada and Nordell	0	2	4	6	0	100	40	140
88	Cameron	Charles Huskon No. 26	0	0	2	2	0	0	20	20
89	Cameron	Charles Huskon No. 11	0	0	2	2	0	0	20	20

Table 2. Groundwater Pathway Score (continued)

MAP-ID	Chapter	Mine Name / Identifier Name	1/4 Mile Wells Count	1 Mile Wells Count	4 Mile Wells Count	Total Wells Count	1/4 Mile Score	1 Mile Score	4 Mile Score	Total Groundwater Score
90		New Liba Group	0	0	2	2	0	0	20	20
91		New Liba Group	0	0	2	2	0	0	20	20
92		Section 9 Lease	0	0	2	2	0	0	20	20
93	Coalmine Canyon	Ramco No. 21	0	0	2	2	0	0	20	20
94	Coalmine Canyon	Ramco No. 20	0	0	3	3	0	0	30	30
95	Coalmine Canyon	Ramco No. 22	0	0	2	2	0	0	20	20
96	Coalmine Canyon	Ryan No. 2	0	0	2	2	0	0	20	20
97	Coalmine Canyon	Ryan No. 3	0	0	2	2	0	0	20	20
98		Section 9 Lease	0	0	3	3	0	0	30	30
99		Section 9 Lease	0	0	3	3	0	0	30	30
100	Coalmine Canyon	Yazzie No. 1	0	0	3	3	0	0	30	30
101	Coalmine Canyon	Yazzie No. 2	0	0	3	3	0	0	30	30
102	Coalmine Canyon	Charles Huskon No. 17	0	0	3	3	0	0	30	30
103	Coalmine Canyon	Jackpot No. 40	0	0	3	3	0	0	30	30
104	Coalmine Canyon	Jackpot No. 1	0	0	3	3	0	0	30	30
105	Coalmine Canyon	Jackpot No. 5	0	0	3	3	0	0	30	30
106		Grub No. 14	0	0	4	4	0	0	40	40
107		Black Point-Murphy Group	0	0	3	3	0	0	30	30
108	Coalmine Canyon	Amos Chee No. 8	0	0	6	6	0	0	60	60
109	Coalmine Canyon	Max Johnson No. 7	0	1	5	6	0	50	50	100
110	Coalmine Canyon	Charles Huskon No. 9	0	1	5	6	0	50	50	100
111	Coalmine Canyon	Emmet Lee No. 1	0	1	5	6	0	50	50	100
112	Coalmine Canyon	Julius Chee No. 4	0	1	6	7	0	50	60	110
113	Coalmine Canyon	Julius Chee No. 3	0	1	5	6	0	50	50	100
114	Coalmine Canyon	Elwood Thompson No. 1	0	1	5	6	0	50	50	100
115	Coalmine Canyon	Ramco No. 24	0	0	7	7	0	0	70	70
116	Coalmine Canyon	Harry Walker No. 16	0	0	7	7	0	0	70	70
117	Coalmine Canyon	Julius Chee No. 2	0	0	6	6	0	0	60	60
118	Coalmine Canyon	Charles Huskon No. 4	0	0	6	6	0	0	60	60
119	Coalmine Canyon	Paul Huskie No. 3	0	0	6	6	0	0	60	60
120	Coalmine Canyon	Charles Huskon No. 18	0	0	6	6	0	0	60	60
121	Coalmine Canyon	Julia Semallie	0	0	6	6	0	0	60	60
122	Coalmine Canyon	Emmet Lee No. 3	0	0	6	6	0	0	60	60
123	Leupp	Adolf Maloney No. 2	0	0	3	3	0	0	30	30
124	Leupp	Amos Chee No. 2 and No. 3	0	0	3	3	0	0	30	30

SOIL PATHWAY AND AIR PATHWAY

The soil exposure pathway involves direct exposure to hazardous substances and areas of suspected contamination. This pathway differs from the three migration pathways in that it accounts for contact with in-place hazardous substances at the site rather than migration of substances from the site. Evaluation of the soil pathway using the modified HRS required the location of the AUM sites and distance to structures. The HRS criteria used to evaluate the soil pathway were:

- For structures within 200 feet of an AUM site, assign 100 points per structure,
- For structures between 200 feet and 1,320 feet, assign 25 points per structure,
- For structures between 1,320 feet and 1 mile, assign 10 points per structure, and
- If no structures exist within 1 mile, assign 0 points.

The air pathway involves wind that can entrain particulates from mine spoil piles, roads, and other disturbed areas. Waste rock at AUM sites contain radionuclides and metals that may be released as fugitive dust where they can be inhaled or ingested. This material can contaminate areas downwind as particles settle out of suspension in the air (EPA, 2000b). Evaluation of the air pathway using the modified HRS also required the location of AUM sites and distance to structures. Figure 4 is a photograph taken from the A&B No. 2 AUM site illustrating the surrounding terrain. The area has sparse vegetation with alluvial deposits that overlie the consolidated sedimentary rocks (Longsworth, 1994), which are conditions that may increase the potential for wind-blown dust.

The buffer distances around the AUM sites and the factors associated with each distance are the same for both the soil and air pathways under the modified HRS used for this assessment. Therefore, a single table was generated for both pathways. Table 3 “Soil Pathway and Air Pathway Score” shows the number of structures that occur within 200 feet, 1,320 feet (1/4 mile), and 1 mile of AUM sites. The number of structures within each buffer are multiplied by the scoring factor for each buffer. The scores for each buffer are summed to obtain the total score for each AUM site. The table was sorted by the MAP-ID number. The highest scored AUM is located at A & B No. 3 in the Cameron Chapter (MAP-ID #39). The soil pathway score for A & B No. 3 is 2,525 and air pathway score is 2,525 for a total soil and air pathway score of 5,050. The soil and air pathway scores calculated for this site are based on 2 structures within 200 feet of the AUM, 33 structures in the 200 foot to 1/4 mile buffer, and 150 structures in the 1/4 mile to 1 mile buffer, for a total of 185 structures within 1 mile of the AUM.

Figure 4. Photograph Taken from A&B No. 2 AUM Site (MAP-ID #56) Located in the Cameron Chapter Looking Northwest.

Table 3. Soil Pathway and Air Pathway Score.

MAP-ID	Chapter	Mine Name / Identifier Name	200 Foot Structures Count	1/4 Mile Structures Count	1 Mile Structures Count	Total Structures Count	200 Foot Score	1/4 Mile Score	1 Mile Score	Total Soil Score	Total Air Score
1	Bodaway/Gap	Jimmie Boone A & B	0	0	0	0	0	0	0	0	0
2	Bodaway/Gap	Tommy	0	0	12	12	0	0	120	120	120
3	Bodaway/Gap	June	0	0	4	4	0	0	40	40	40
4	Bodaway/Gap	Thomas No. 1	0	0	1	1	0	0	10	10	10
5	Bodaway/Gap	Martin Johnson No. 4	0	8	29	37	0	200	290	490	490
6	Bodaway/Gap	Earl Huskon No. 1	0	0	1	1	0	0	10	10	10
7	Bodaway/Gap	Max Huskon No. 5	0	0	0	0	0	0	0	0	0
8	Bodaway/Gap	Paul Huskie No. 21	0	0	0	0	0	0	0	0	0
9	Bodaway/Gap	Earl Huskon No. 3	0	0	0	0	0	0	0	0	0
10	Bodaway/Gap	A & B No. 5	0	0	0	0	0	0	0	0	0
11	Bodaway/Gap	Max Huskon No. 1	0	0	4	4	0	0	40	40	40
12	Bodaway/Gap	Henry Sloan No. 1	0	4	1	5	0	100	10	110	110
13	Bodaway/Gap	Henry Sloan No. 1	0	3	2	5	0	75	20	95	95
14	Bodaway/Gap	Charles Huskon No. 7 (MP-357)	0	1	0	1	0	25	0	25	25
15	Bodaway/Gap	A & B No. 13	0	0	8	8	0	0	80	80	80
16	Bodaway/Gap	A & B No. 7	0	0	5	5	0	0	50	50	50
17	Coalmine Canyon	Charles Huskon No. 5	0	0	2	2	0	0	20	20	20
18	Coalmine Canyon	Charles Huskon No. 6	0	1	2	3	0	25	20	45	45
19	Coalmine Canyon	Lemuel Littleman No. 7	0	0	4	4	0	0	40	40	40
20	Coalmine Canyon	Jeepster No. 1	0	0	6	6	0	0	60	60	60
21	Bodaway/Gap	Montezuma No. 7C	0	0	0	0	0	0	0	0	0
22	Bodaway/Gap	Montezuma No. 7B	0	0	0	0	0	0	0	0	0
23	Bodaway/Gap	Montezuma No. 7B	0	0	0	0	0	0	0	0	0
24	Bodaway/Gap	Montezuma No. 7A	0	0	0	0	0	0	0	0	0
25	Bodaway/Gap	Montezuma No. 2	0	0	0	0	0	0	0	0	0
26	Bodaway/Gap	Montezuma No. 2	0	0	0	0	0	0	0	0	0
27	Bodaway/Gap	Montezuma No. 2	0	0	15	15	0	0	150	150	150
28	Coalmine Canyon	Casey No. 3	0	4	9	13	0	100	90	190	190
29	Coalmine Canyon	Jack Daniels No. 3	0	0	0	0	0	0	0	0	0
30	Coalmine Canyon	Kachina No. 6	0	1	18	19	0	25	180	205	205
31	Coalmine Canyon	Charles Huskon No. 19	0	0	16	16	0	0	160	160	160
32	Coalmine Canyon	Charles Huskon No. 19	0	3	19	22	0	75	190	265	265
33	Coalmine Canyon	Jack Daniels No. 5	0	1	53	54	0	25	530	555	555
34	Coalmine Canyon	Jack Daniels No. 1	0	3	48	51	0	75	480	555	555
35	Coalmine Canyon	Jack Daniels No. 4	0	0	52	52	0	0	520	520	520
36	Coalmine Canyon	Evans Huskon No. 34	0	0	2	2	0	0	20	20	20
37	Coalmine Canyon	Charles Huskon No. 20	0	0	2	2	0	0	20	20	20
38	Coalmine Canyon	Charles Huskon No. 12	0	8	36	44	0	200	360	560	560
39	Cameron	A & B No. 3	2	33	150	185	200	825	1500	2525	2525
40	Coalmine Canyon	Max Johnson No. 1	0	0	43	43	0	0	430	430	430
41	Coalmine Canyon	Charles Huskon No. 1	0	0	59	59	0	0	590	590	590
42	Coalmine Canyon	Max Johnson No. 10	0	0	36	36	0	0	360	360	360
43	Coalmine Canyon	Lemuel Littleman No. 2	0	0	26	26	0	0	260	260	260
44	Coalmine Canyon	Harvey Begay No. 1	0	0	0	0	0	0	0	0	0
45	Coalmine Canyon	Max Johnson No. 9	0	0	0	0	0	0	0	0	0
46	Coalmine Canyon	Elwood Canyon No. 1	0	0	0	0	0	0	0	0	0
47	Coalmine Canyon	Alyce Tolino No. 1 & 3	0	0	11	11	0	0	110	110	110
48	Coalmine Canyon	Evans Huskon No. 2	0	0	4	4	0	0	40	40	40
49	Coalmine Canyon	Yazzie No. 101	0	0	4	4	0	0	40	40	40
50	Coalmine Canyon	Yazzie No. 312	0	0	7	7	0	0	70	70	70
51	Coalmine Canyon	Boyd Tisi No. 2	0	4	3	7	0	100	30	130	130
52	Coalmine Canyon	Juan Horse No. 3	0	4	3	7	0	100	30	130	130
53	Cameron	Lemuel Littleman No. 3	0	0	17	17	0	0	170	170	170
54	Coalmine Canyon	Juan Horse No. 4	0	0	7	7	0	0	70	70	70
55	Coalmine Canyon	Pat Lynch	0	0	0	0	0	0	0	0	0
56	Cameron	A & B No. 2	0	1	88	89	0	25	880	905	905
57	Cameron	Charles Huskon No. 14	0	1	0	1	0	25	0	25	25
58	Cameron	Harry Walker No. 19	0	0	2	2	0	0	20	20	20
59	Cameron	Montezuma No. 1	0	0	1	1	0	0	10	10	10
60	Coalmine Canyon	Manuel Denetsone No. 2	0	0	0	0	0	0	0	0	0
61	Coalmine Canyon	Jefferson Canyon No. 1	0	0	0	0	0	0	0	0	0
62	Cameron	Charles Huskon No. 3	0	0	0	0	0	0	0	0	0
63	Cameron	Charles Huskon No. 3	0	0	0	0	0	0	0	0	0
64	Cameron	Charles Huskon No. 3	0	0	0	0	0	0	0	0	0
65	Cameron	Charles Huskon No. 3	0	0	1	1	0	0	10	10	10
66	Coalmine Canyon	Jack Huskon No. 3	0	0	0	0	0	0	0	0	0
67	Cameron	Black Hair No.4	0	0	19	19	0	0	190	190	190
68	Cameron	Paul Huskie No. 20	0	0	11	11	0	0	110	110	110
69	Cameron	Huskon No. 7	0	0	0	0	0	0	0	0	0
70	Cameron	Yazzie No. 102	0	0	0	0	0	0	0	0	0
71	Coalmine Canyon	Yellow Jeep No. 7A and 7B	0	0	0	0	0	0	0	0	0
72	Cameron	Yazzie No. 105	0	0	0	0	0	0	0	0	0
73	Cameron	Charles Huskon No. 10	0	0	0	0	0	0	0	0	0
74	Cameron	Charles Huskon No. 10	0	0	1	1	0	0	10	10	10
75	Coalmine Canyon	Lloyd House	0	0	0	0	0	0	0	0	0
76	Cameron	Charles Huskon No. 8	0	0	0	0	0	0	0	0	0
77	Cameron	Charles Huskon No. 8	0	0	0	0	0	0	0	0	0
78	Cameron	Boyd Tisi No. 1	0	0	0	0	0	0	0	0	0
79	Coalmine Canyon	Evans Huskon No. 35	0	0	0	0	0	0	0	0	0
80	Coalmine Canyon	Cam061	0	0	0	0	0	0	0	0	0
81	Coalmine Canyon	Mel Gardner	0	0	1	1	0	0	10	10	10
82	Coalmine Canyon	Ryan No. 1	0	0	0	0	0	0	0	0	0
83	Cameron	Taylor Reid No. 2	0	0	1	1	0	0	10	10	10
84	Cameron	Taylor Reid No. 3	0	0	1	1	0	0	10	10	10
85		Section 1 Lease	0	0	1	1	0	0	10	10	10
86		Section 1 Lease	0	0	1	1	0	0	10	10	10
87		Ada and Nordell	0	0	1	1	0	0	10	10	10
88	Cameron	Charles Huskon No. 26	0	0	1	1	0	0	10	10	10
89	Cameron	Charles Huskon No. 11	0	0	1	1	0	0	10	10	10

Table 3. Soil Pathway and Air Pathway Score (continued)

MAP-ID	Chapter	Mine Name / Identifier Name	200 Foot Structures Count	1/4 Mile Structures Count	1 Mile Structures Count	Total Structures Count	200 Foot Score	1/4 Mile Score	1 Mile Score	Total Soil Score	Total Air Score
90		New Liba Group	0	0	0	0	0	0	0	0	0
91		New Liba Group	0	0	0	0	0	0	0	0	0
92		Section 9 Lease	0	0	0	0	0	0	0	0	0
93	Coalmine Canyon	Ramco No. 21	0	1	0	1	0	25	0	25	25
94	Coalmine Canyon	Ramco No. 20	0	1	1	2	0	25	10	35	35
95	Coalmine Canyon	Ramco No. 22	0	1	1	2	0	25	10	35	35
96	Coalmine Canyon	Ryan No. 2	0	0	2	2	0	0	20	20	20
97	Coalmine Canyon	Ryan No. 3	0	0	2	2	0	0	20	20	20
98		Section 9 Lease	0	0	0	0	0	0	0	0	0
99		Section 9 Lease	0	0	0	0	0	0	0	0	0
100	Coalmine Canyon	Yazzie No. 1	0	0	1	1	0	0	10	10	10
101	Coalmine Canyon	Yazzie No. 2	0	0	2	2	0	0	20	20	20
102	Coalmine Canyon	Charles Huskon No. 17	0	0	2	2	0	0	20	20	20
103	Coalmine Canyon	Jackpot No. 40	0	0	1	1	0	0	10	10	10
104	Coalmine Canyon	Jackpot No. 1	0	0	2	2	0	0	20	20	20
105	Coalmine Canyon	Jackpot No. 5	0	0	1	1	0	0	10	10	10
106		Grub No. 14	0	0	0	0	0	0	0	0	0
107		Black Point-Murphy Group	0	1	2	3	0	25	20	45	45
108	Coalmine Canyon	Amos Chee No. 8	0	0	1	1	0	0	10	10	10
109	Coalmine Canyon	Max Johnson No. 7	0	0	0	0	0	0	0	0	0
110	Coalmine Canyon	Charles Huskon No. 9	0	0	3	3	0	0	30	30	30
111	Coalmine Canyon	Emmet Lee No. 1	0	0	3	3	0	0	30	30	30
112	Coalmine Canyon	Julius Chee No. 4	0	0	3	3	0	0	30	30	30
113	Coalmine Canyon	Julius Chee No. 3	0	0	3	3	0	0	30	30	30
114	Coalmine Canyon	Elwood Thompson No. 1	0	0	3	3	0	0	30	30	30
115	Coalmine Canyon	Ramco No. 24	0	0	4	4	0	0	40	40	40
116	Coalmine Canyon	Harry Walker No. 16	0	0	1	1	0	0	10	10	10
117	Coalmine Canyon	Julius Chee No. 2	0	0	3	3	0	0	30	30	30
118	Coalmine Canyon	Charles Huskon No. 4	0	0	4	4	0	0	40	40	40
119	Coalmine Canyon	Paul Huskie No. 3	0	0	4	4	0	0	40	40	40
120	Coalmine Canyon	Charles Huskon No. 18	0	0	3	3	0	0	30	30	30
121	Coalmine Canyon	Julia Semallie	0	0	1	1	0	0	10	10	10
122	Coalmine Canyon	Emmet Lee No. 3	0	0	1	1	0	0	10	10	10
123	Leupp	Adolf Maloney No. 2	0	0	4	4	0	0	40	40	40
124	Leupp	Amos Chee No. 2 and No. 3	0	0	0	0	0	0	0	0	0

COMBINED PATHWAYS

Once total scores were developed for each of the four pathways it was possible to tabulate a combined pathways score for each of the AUM sites. Scores for air, soil, surface water, and groundwater were summed to obtain combined scores, which are presented in Table 4 “Combined Pathway Score.” The table was sorted by MAP-ID number. Figure 5 (on page 16) shows photographic examples of modified HRS scoring factors found in the Western AUM Region.

The GIS database was used to generate several maps depicting the combined pathways results. Figure 6 “Combined Pathways – Map Figure Index” (on page 17) shows the AUM sites and the extents of the aggregated buffers that were generated around the AUM sites. Also shown on Figure 6 are the extents of the six map enlargements for the combined pathways:

Figure 7 Combined Pathways in the Echo Cliffs Region
Figure 8 Combined Pathways in the Southeastern Bodaway/Gap Region
Figure 9 Combined Pathways in the Cameron Region
Figure 10 Combined Pathways in the Adeii Eechii Cliffs Region
Figure 11 Combined Pathways in the Southern Little Colorado Region
Figure 12 Combined Pathways in the East Black Falls Region

The map enlargements show the AUM sites labeled with their corresponding MAP-ID, as well as structures, wells, and drainages. Table 5 below lists the map figure number and the range of MAP-IDs on each map. Also shown on the maps are sites that have been entered into the EPA’s Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). Additional information regarding the CERCLIS sites can be obtained from EPA Region 9.

FIGURE NUMBER	RANGE OF MAP-IDS
Figure 7	1-4
Figure 8	5-17
Figure 9	18-70
Figure 10	71
Figure 11	72-122
Figure 12	123-124

Table 5. MAP-ID Correspondence to Figure Number.

Based on the modified HRS model used for this assessment, scores for AUM sites within the Western AUM Region range from 10 to 5,760. The AUM site identified by MAP-ID #39 (A & B No. 3) has the highest combined pathway score (5,760) within the Western AUM Region. Figure 9 shows the location of MAP ID #39. In this map figure it is possible to see the Air and Soil Pathway contributions of 2 structures within the 200 foot buffer around the AUM, 33 structures between 200 feet and 1/4 mile, and 150 structures between 1/4 mile and 1 mile. The Groundwater Pathway contributions are shown by 0 wells within 1/4 mile, 8 wells between 1/4 mile and 1 mile, and 15 wells between 1 mile and 4 miles of the AUM site. The Surface Water Pathway contribution is shown by the downstream drainage from the AUM site through each of the buffers.

Table 4. Combined Pathway Score.

MAP-ID	Chapter	Mine Name / Identifier Name	Total Air Score	Total Soil Score	Total Groundwater Score	Total Surface Water Score	Combined Score
1	Bodaway/Gap	Jimmie Boone A & B	0	0	30	160	190
2	Bodaway/Gap	Tommy	120	120	50	160	450
3	Bodaway/Gap	June	40	40	50	160	290
4	Bodaway/Gap	Thomas No. 1	10	10	190	160	370
5	Bodaway/Gap	Martin Johnson No. 4	490	490	110	160	1250
6	Bodaway/Gap	Earl Huskon No. 1	10	10	20	160	200
7	Bodaway/Gap	Max Huskon No. 5	0	0	30	160	190
8	Bodaway/Gap	Paul Huskie No. 21	0	0	30	160	190
9	Bodaway/Gap	Earl Huskon No. 3	0	0	30	160	190
10	Bodaway/Gap	A & B No. 5	0	0	20	160	180
11	Bodaway/Gap	Max Huskon No. 1	40	40	20	160	260
12	Bodaway/Gap	Henry Sloan No. 1	110	110	30	160	410
13	Bodaway/Gap	Henry Sloan No. 1	95	95	20	160	370
14	Bodaway/Gap	Charles Huskon No. 7 (MP-357)	25	25	20	160	230
15	Bodaway/Gap	A & B No. 13	80	80	70	160	390
16	Bodaway/Gap	A & B No. 7	50	50	40	160	300
17	Coalmine Canyon	Charles Huskon No. 5	20	20	40	160	240
18	Coalmine Canyon	Charles Huskon No. 6	45	45	40	160	290
19	Coalmine Canyon	Lemuel Littleman No. 7	40	40	80	160	320
20	Coalmine Canyon	Jeepster No. 1	60	60	80	160	360
21	Bodaway/Gap	Montezuma No. 7C	0	0	30	160	190
22	Bodaway/Gap	Montezuma No. 7B	0	0	30	160	190
23	Bodaway/Gap	Montezuma No. 7B	0	0	90	160	250
24	Bodaway/Gap	Montezuma No. 7A	0	0	110	160	270
25	Bodaway/Gap	Montezuma No. 2	0	0	110	160	270
26	Bodaway/Gap	Montezuma No. 2	0	0	110	160	270
27	Bodaway/Gap	Montezuma No. 2	150	150	110	160	570
28	Coalmine Canyon	Casey No. 3	190	190	110	160	650
29	Coalmine Canyon	Jack Daniels No. 3	0	0	50	160	210
30	Coalmine Canyon	Kachina No. 6	205	205	170	160	740
31	Coalmine Canyon	Charles Huskon No. 19	160	160	170	160	650
32	Coalmine Canyon	Charles Huskon No. 19	265	265	220	160	910
33	Coalmine Canyon	Jack Daniels No. 5	555	555	280	160	1550
34	Coalmine Canyon	Jack Daniels No. 1	555	555	230	160	1500
35	Coalmine Canyon	Jack Daniels No. 4	520	520	300	160	1500
36	Coalmine Canyon	Evans Huskon No. 34	20	20	60	160	260
37	Coalmine Canyon	Charles Huskon No. 20	20	20	60	160	260
38	Coalmine Canyon	Charles Huskon No. 12	560	560	210	160	1490
39	Cameron	A & B No. 3	2525	2525	550	160	5760
40	Coalmine Canyon	Max Johnson No. 1	430	430	280	160	1300
41	Coalmine Canyon	Charles Huskon No. 1	590	590	320	160	1660
42	Coalmine Canyon	Max Johnson No. 10	360	360	320	160	1200
43	Coalmine Canyon	Lemuel Littleman No. 2	260	260	180	160	860
44	Coalmine Canyon	Harvey Begay No. 1	0	0	160	160	320
45	Coalmine Canyon	Max Johnson No. 9	0	0	260	160	420
46	Coalmine Canyon	Elwood Canyon No. 1	0	0	210	160	370
47	Coalmine Canyon	Alyce Tolino No. 1 & 3	110	110	260	160	640
48	Coalmine Canyon	Evans Huskon No. 2	40	40	260	160	500
49	Coalmine Canyon	Yazzie No. 101	40	40	250	160	490
50	Coalmine Canyon	Yazzie No. 312	70	70	260	160	560
51	Coalmine Canyon	Boyd Tisi No. 2	130	130	340	160	760
52	Coalmine Canyon	Juan Horse No. 3	130	130	340	160	760
53	Cameron	Lemuel Littleman No. 3	170	170	240	160	740
54	Coalmine Canyon	Juan Horse No. 4	70	70	250	160	550
55	Coalmine Canyon	Pat Lynch	0	0	60	160	220
56	Cameron	A & B No. 2	905	905	420	160	2390
57	Cameron	Charles Huskon No. 14	25	25	250	160	460
58	Cameron	Harry Walker No. 19	20	20	190	160	390
59	Cameron	Montezuma No. 1	10	10	230	160	410
60	Coalmine Canyon	Manuel Denetsone No. 2	0	0	210	160	370
61	Coalmine Canyon	Jefferson Canyon No. 1	0	0	140	160	300
62	Cameron	Charles Huskon No. 3	0	0	110	160	270
63	Cameron	Charles Huskon No. 3	0	0	80	160	240
64	Cameron	Charles Huskon No. 3	0	0	90	160	250
65	Cameron	Charles Huskon No. 3	10	10	110	160	290
66	Coalmine Canyon	Jack Huskon No. 3	0	0	60	160	220
67	Cameron	Black Hair No.4	190	190	180	160	720
68	Cameron	Paul Huskie No. 20	110	110	70	160	450
69	Cameron	Huskon No. 7	0	0	70	160	230
70	Cameron	Yazzie No. 102	0	0	70	160	230
71	Coalmine Canyon	Yellow Jeep No. 7A and 7B	0	0	10	160	170
72	Cameron	Yazzie No. 105	0	0	40	160	200
73	Cameron	Charles Huskon No. 10	0	0	60	160	220
74	Cameron	Charles Huskon No. 10	10	10	60	160	240
75	Coalmine Canyon	Lloyd House	0	0	10	160	170
76	Cameron	Charles Huskon No. 8	0	0	50	160	210
77	Cameron	Charles Huskon No. 8	0	0	90	160	250
78	Cameron	Boyd Tisi No. 1	0	0	90	160	250
79	Coalmine Canyon	Evans Huskon No. 35	0	0	10	0	10
80	Coalmine Canyon	Cam061	0	0	10	0	10
81	Coalmine Canyon	Mel Gardner	10	10	20	160	200
82	Coalmine Canyon	Ryan No. 1	0	0	20	160	180
83	Cameron	Taylor Reid No. 2	10	10	140	160	320
84	Cameron	Taylor Reid No. 3	10	10	110	160	290
85		Section 1 Lease	10	10	100	160	280
86		Section 1 Lease	10	10	110	160	290
87		Ada and Nordell	10	10	140	160	320
88	Cameron	Charles Huskon No. 26	10	10	20	160	200
89	Cameron	Charles Huskon No. 11	10	10	20	160	200

Table 4. Combined Pathway Score (continued).

MAP-ID	Chapter	Mine Name / Identifier Name	Total Air Score	Total Soil Score	Total Groundwater Score	Total Surface Water Score	Combined Score
90		New Liba Group	0	0	20	160	180
91		New Liba Group	0	0	20	160	180
92		Section 9 Lease	0	0	20	160	180
93	Coalmine Canyon	Ramco No. 21	25	25	20	160	230
94	Coalmine Canyon	Ramco No. 20	35	35	30	160	260
95	Coalmine Canyon	Ramco No. 22	35	35	20	160	250
96	Coalmine Canyon	Ryan No. 2	20	20	20	160	220
97	Coalmine Canyon	Ryan No. 3	20	20	20	160	220
98		Section 9 Lease	0	0	30	160	190
99		Section 9 Lease	0	0	30	160	190
100	Coalmine Canyon	Yazzie No. 1	10	10	30	160	210
101	Coalmine Canyon	Yazzie No. 2	20	20	30	160	230
102	Coalmine Canyon	Charles Huskon No. 17	20	20	30	160	230
103	Coalmine Canyon	Jackpot No. 40	10	10	30	160	210
104	Coalmine Canyon	Jackpot No. 1	20	20	30	160	230
105	Coalmine Canyon	Jackpot No. 5	10	10	30	160	210
106		Grub No. 14	0	0	40	160	200
107		Black Point-Murphy Group	45	45	30	160	280
108	Coalmine Canyon	Amos Chee No. 8	10	10	60	160	240
109	Coalmine Canyon	Max Johnson No. 7	0	0	100	160	260
110	Coalmine Canyon	Charles Huskon No. 9	30	30	100	160	320
111	Coalmine Canyon	Emmet Lee No. 1	30	30	100	160	320
112	Coalmine Canyon	Julius Chee No. 4	30	30	110	160	330
113	Coalmine Canyon	Julius Chee No. 3	30	30	100	160	320
114	Coalmine Canyon	Elwood Thompson No. 1	30	30	100	160	320
115	Coalmine Canyon	Ramco No. 24	40	40	70	160	310
116	Coalmine Canyon	Harry Walker No. 16	10	10	70	160	250
117	Coalmine Canyon	Julius Chee No. 2	30	30	60	160	280
118	Coalmine Canyon	Charles Huskon No. 4	40	40	60	160	300
119	Coalmine Canyon	Paul Huskie No. 3	40	40	60	160	300
120	Coalmine Canyon	Charles Huskon No. 18	30	30	60	160	280
121	Coalmine Canyon	Julia Semallie	10	10	60	160	240
122	Coalmine Canyon	Emmet Lee No. 3	10	10	60	160	240
123	Leupp	Adolf Maloney No. 2	40	40	30	160	270
124	Leupp	Amos Chee No. 2 and No. 3	0	0	30	160	190

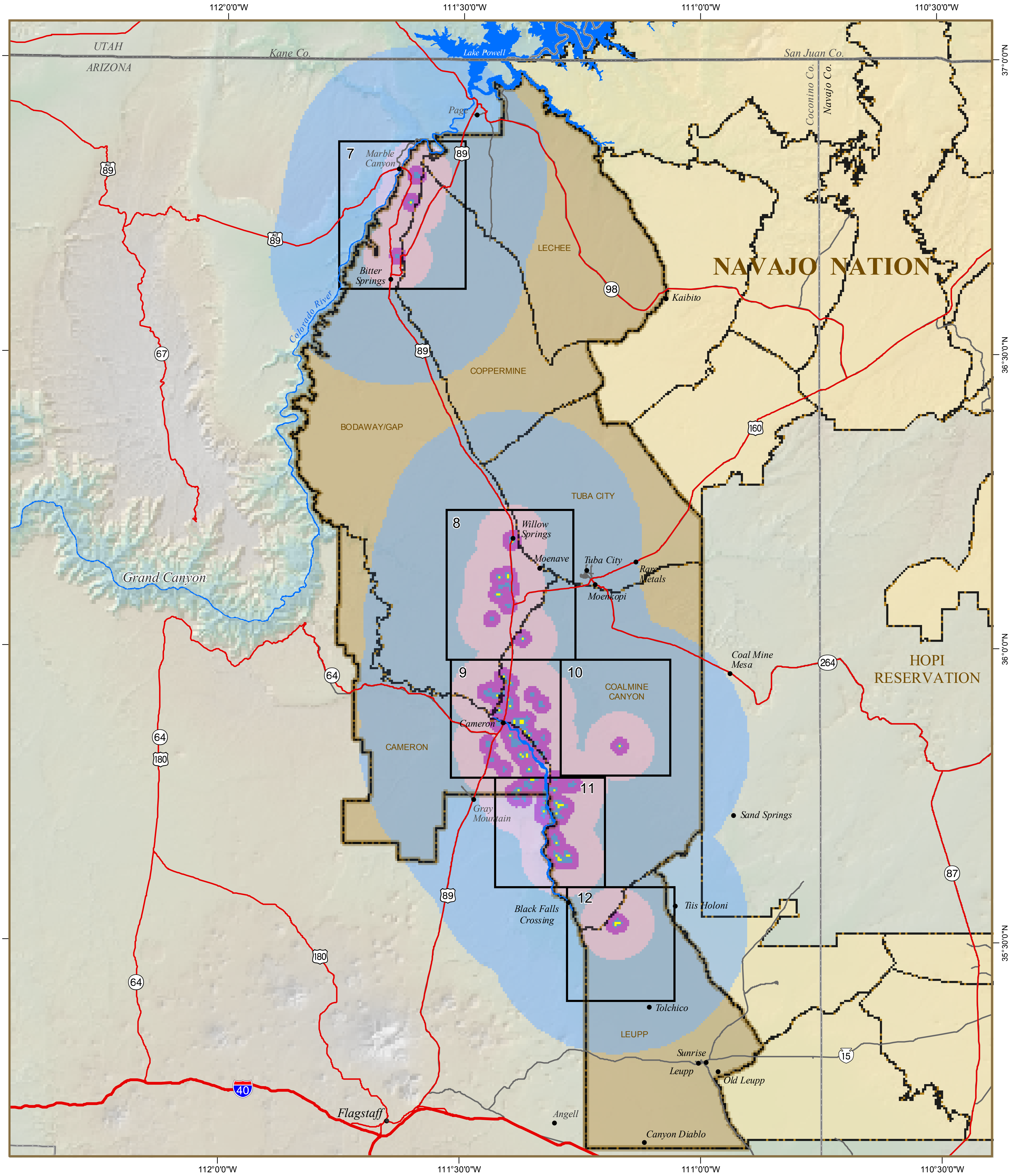

Abandoned Uranium Mine


Structures


Wells


Surface Water

Figure 5. Example Photographs of Modified HRS Scoring Factors.



ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Western AUM Region Screening Assessment Report

COMBINED PATHWAYS - MAP FIGURE INDEX

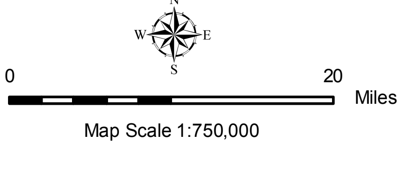
Sources

Uranium mine areas are primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by other sources. The Navajo Nation and Chapter boundaries are from the Navajo Lands Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Selected Populated Places are from the USGS Geographic Names Information System (GNIS). Buffers were generated by TerraSpectra Geomatics. Map index area boundaries are approximate.

Map Index Area Designations

Figure

- 7 - Echo Cliffs
- 8 - Southeastern Bodaway/Gap
- 9 - Cameron
- 10 - Adeii Eechii Cliffs
- 11 - Southern Little Colorado
- 12 - East Black Falls



Legend

- Western AUM Region
- Uranium Mine
- Mine Buffers
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles
- Populated Places
- Highway
- Paved Road

Figure 6. Combined Pathways Map Figure Index.

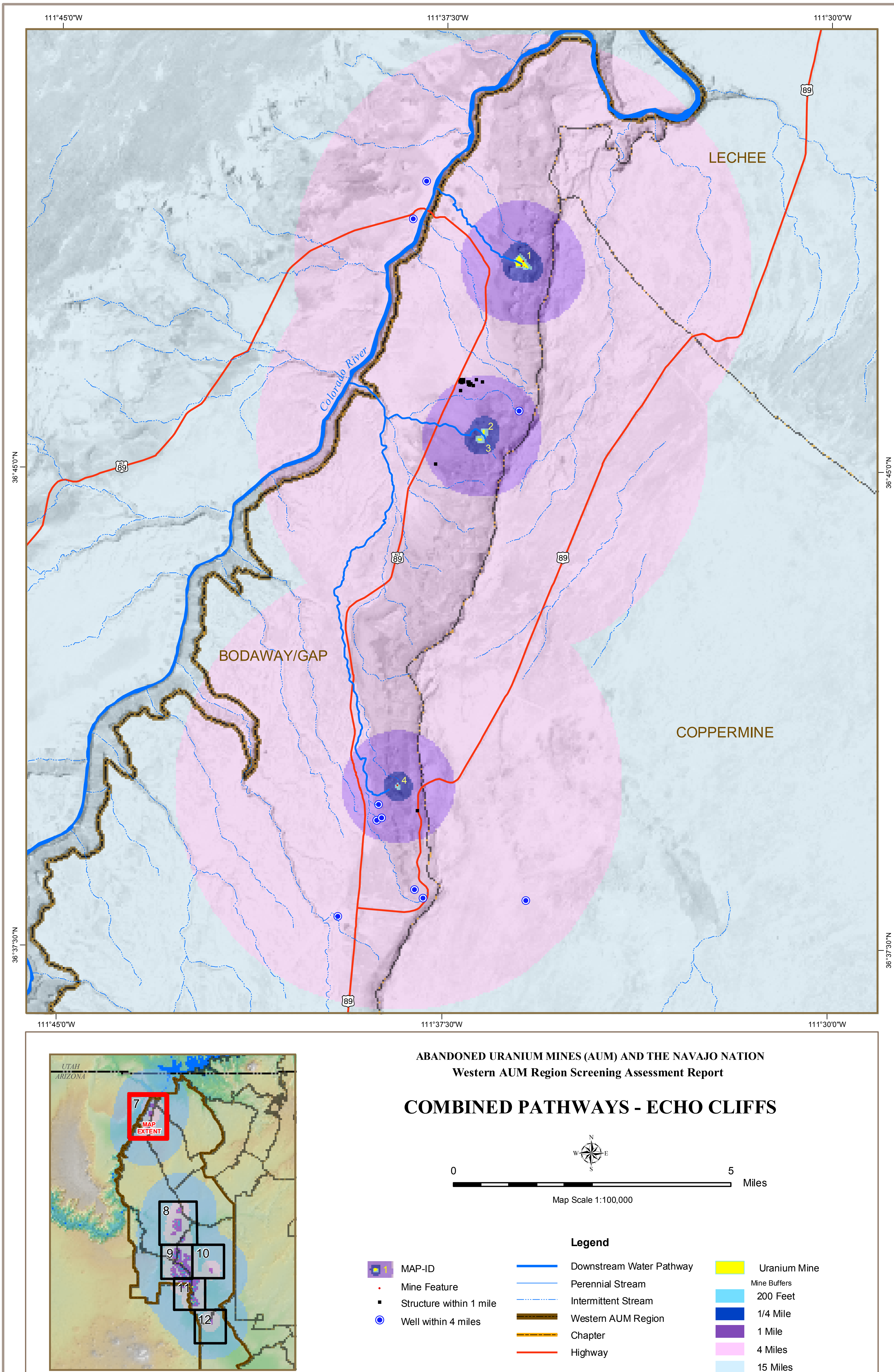
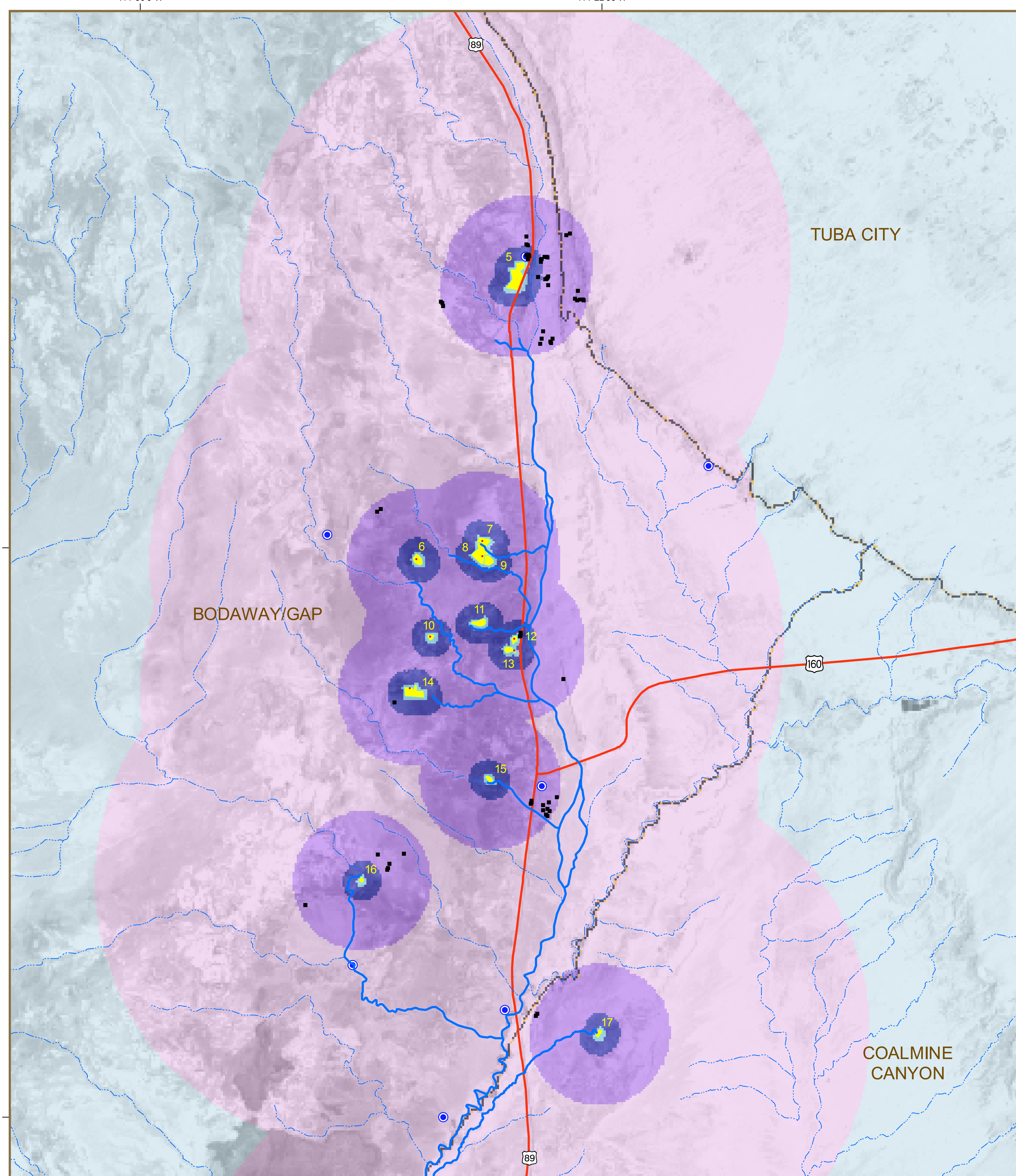
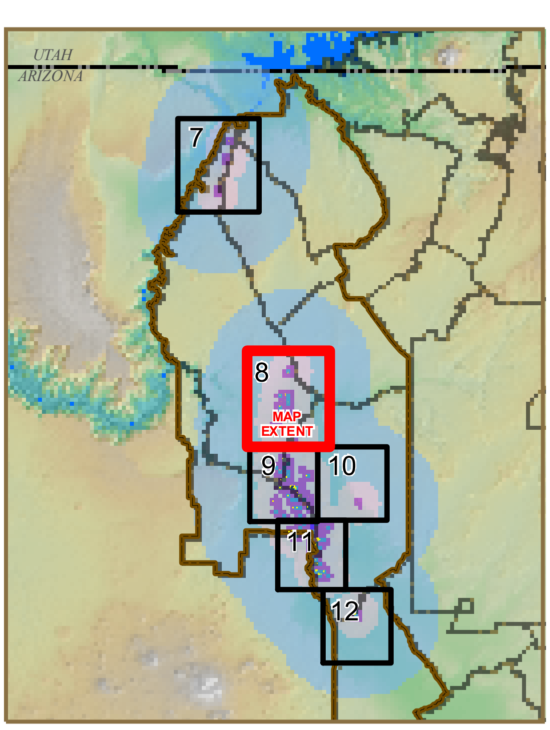


Figure 7. Combined Pathways in the Echo Cliffs Region.





ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Western AUM Region Screening Assessment Report

COMBINED PATHWAYS - SOUTHEASTERN BODAWAY/GAP

N
W E
S

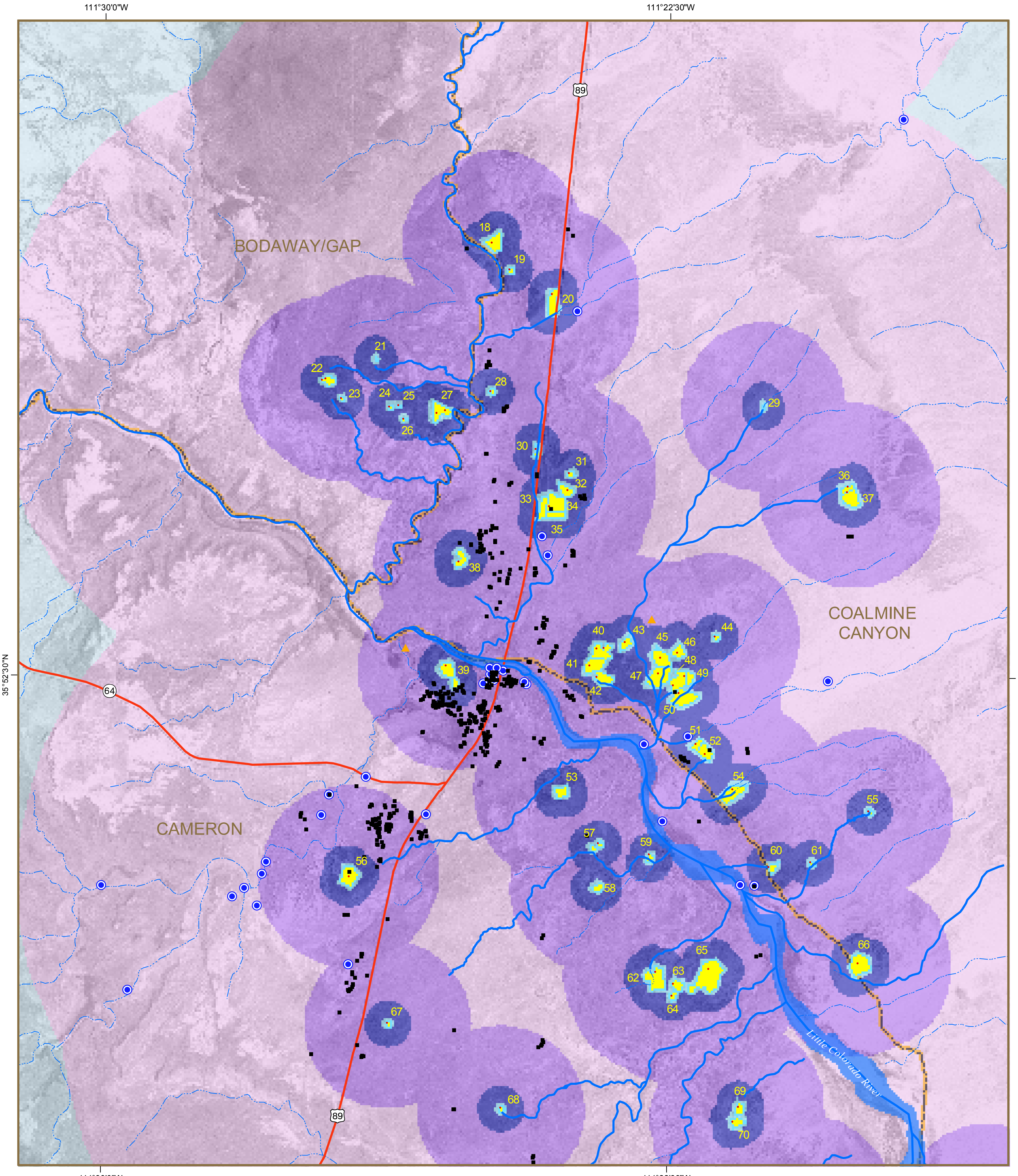
0 5
Miles

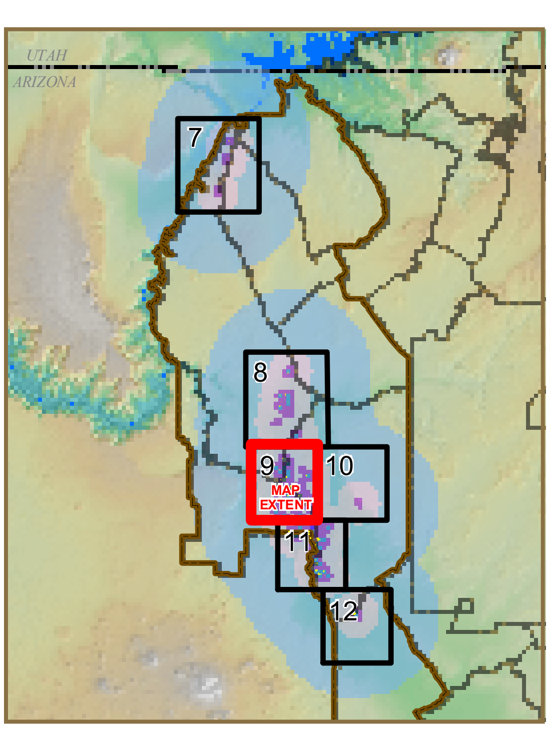
Map Scale 1:100,000

Legend

5 MAP-ID	Downstream Water Pathway	Uranium Mine
Mine Feature	Intermittent Stream	Mine Buffers
Structure within 1 mile	Chapter	200 Feet
Well within 4 miles	Highway	1/4 Mile
		1 Mile
		4 Miles
		15 Miles

Figure 8. Combined Pathways in the Southeastern Bodaway/Gap Region.





ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Western AUM Region Screening Assessment Report

COMBINED PATHWAYS - CAMERON

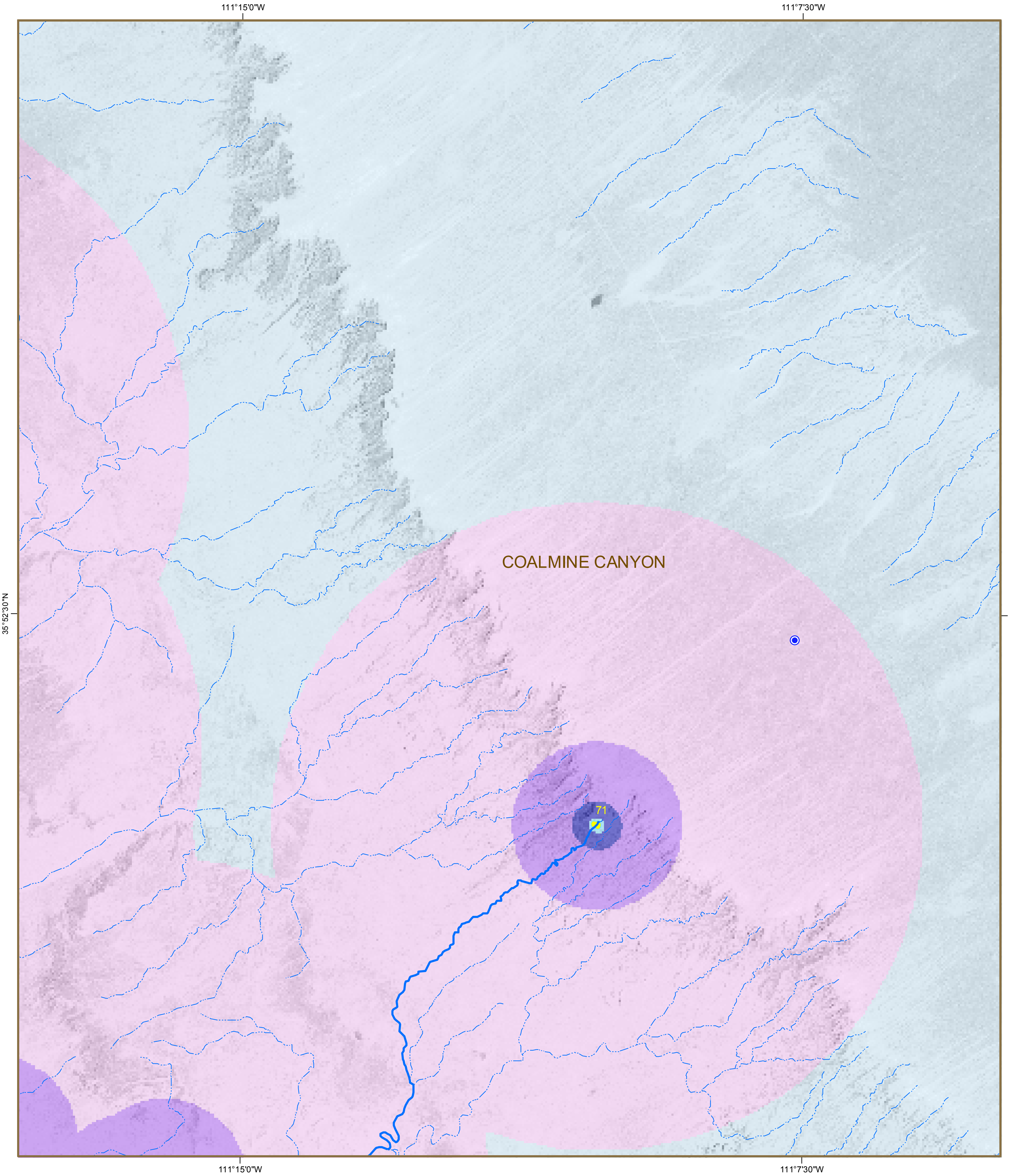
0 4 Miles

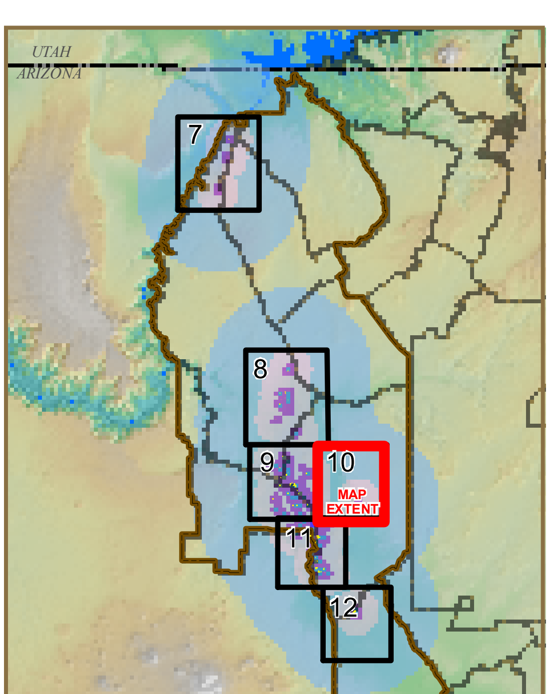
Map Scale 1:80,000

Legend

- 18 MAP-ID
- Mine Feature
- CERCLIS Project
- Structure within 1 mile
- Well within 4 miles
- Downstream Water Pathway
- Perennial Stream
- Intermittent Stream
- Chapter
- Highway
- Uranium Mine
- Mine Buffers
  - 200 Feet
  - 1/4 Mile
  - 1 Mile
  - 4 Miles
  - 15 Miles

Figure 9. Combined Pathways in the Cameron Region.





ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Western AUM Region Screening Assessment Report

COMBINED PATHWAYS - ADEII EECHI CLIFFS

N
W E
S

0 4 Miles

Map Scale 1:80,000

Legend

- 71 MAP-ID
- Well within 4 miles
- Downstream Water Pathway
- Intermittent Stream
- Chapter
- Uranium Mine

Mine Buffers

- 200 Feet
- 1/4 Mile
- 1 Mile
- 4 Miles
- 15 Miles

Figure 10. Combined Pathways in the Adeii Eechi Cliffs Region.

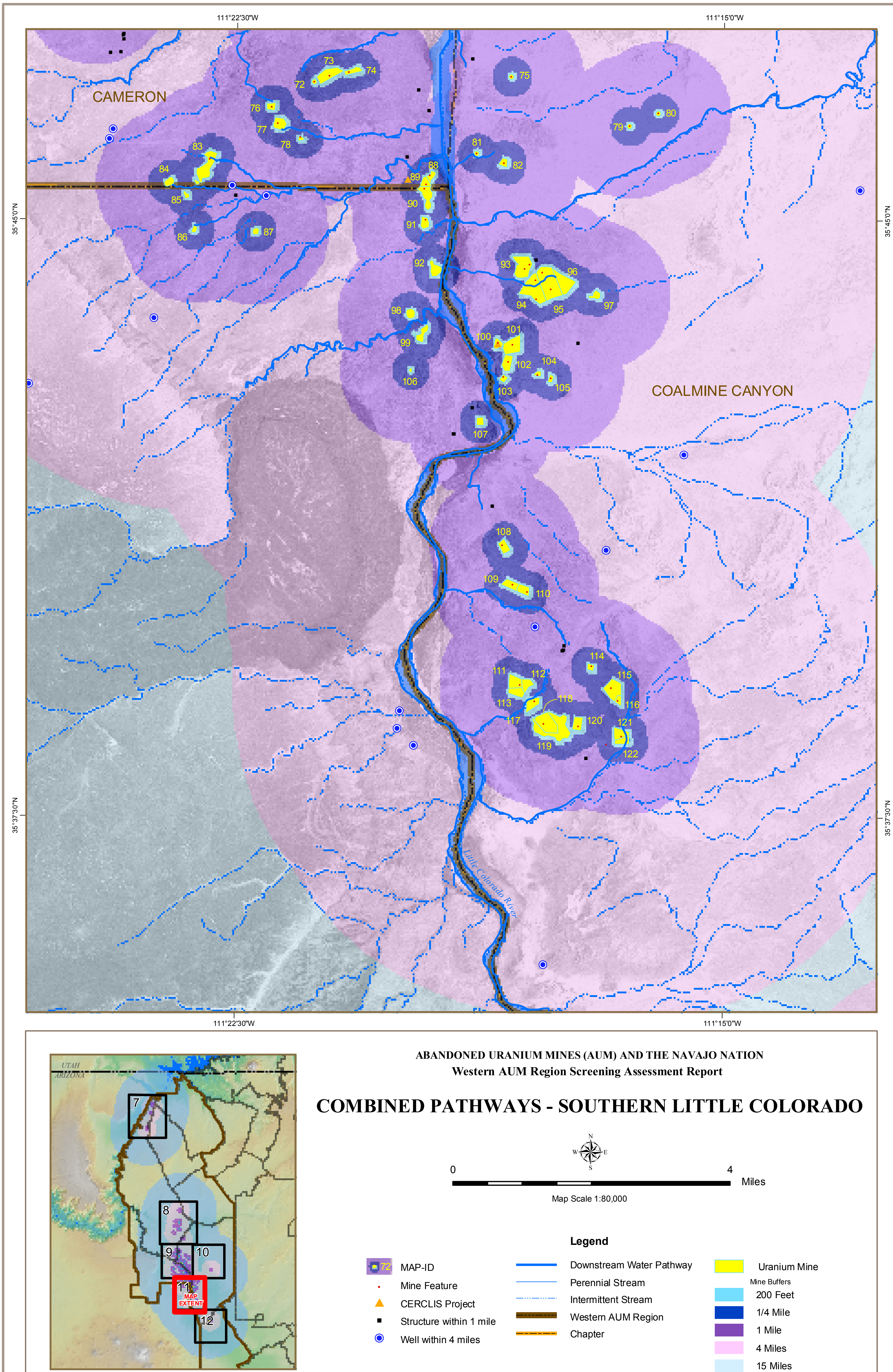
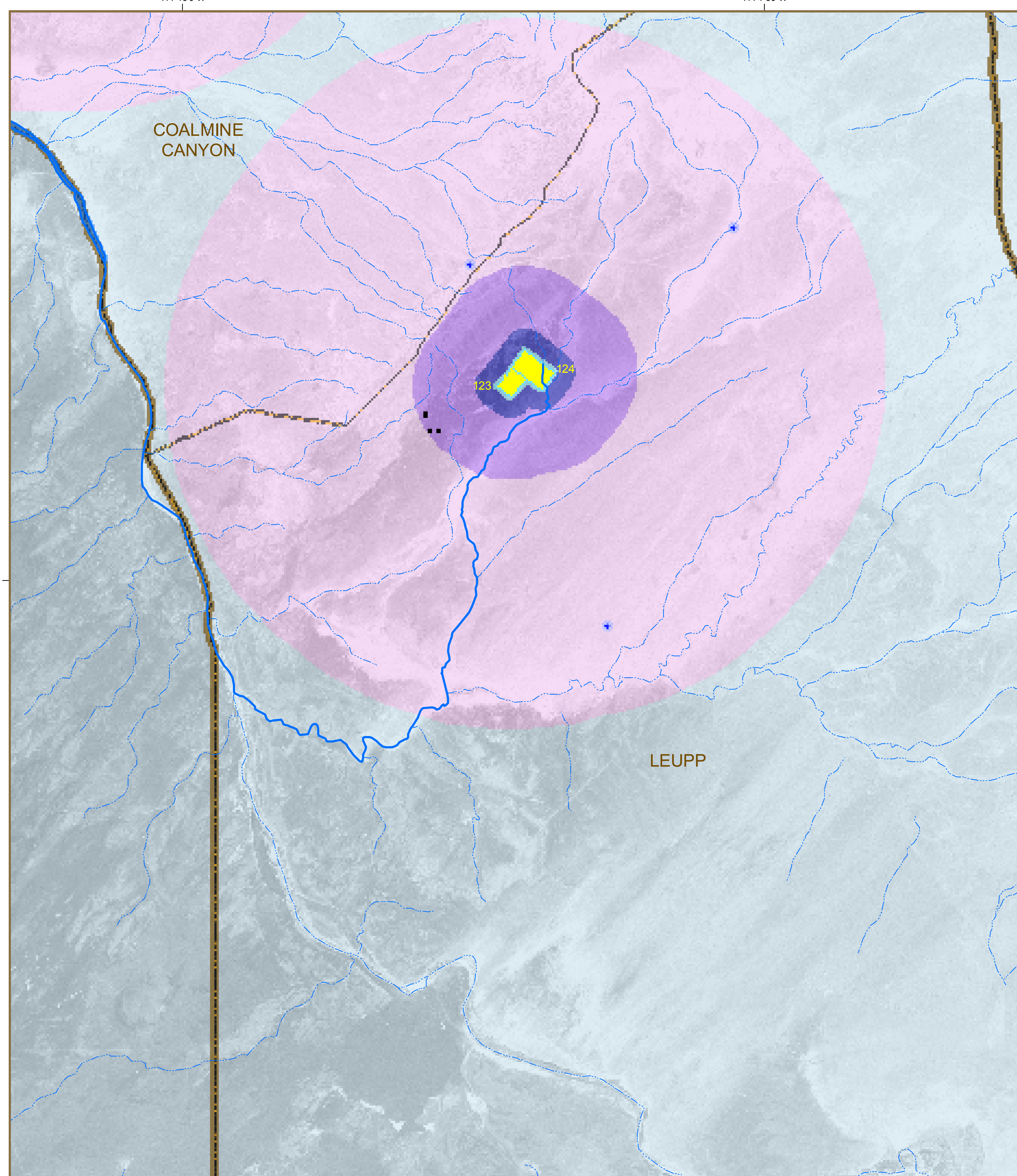
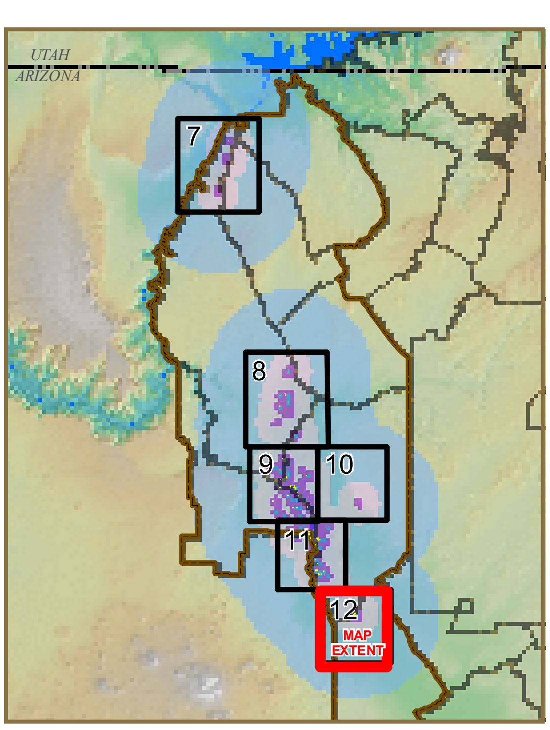


Figure 11. Combined Pathways in the Southern Little Colorado Region.





ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION
Western AUM Region Screening Assessment Report

COMBINED PATHWAYS - EAST BLACK FALLS

N W E S

0 4 Miles

Map Scale 1:80,000

Legend

123 MAP-ID
Structure within 1 mile
Well within 4 miles

Downstream Water Pathway
Perennial Stream
Intermittent Stream
Western AUM Region
Chapter

Uranium Mine
Mine Buffers
200 Feet
1/4 Mile
1 Mile
4 Miles
15 Miles

Figure 12. Combined Pathways in the East Black Falls Region.

DISCUSSION

Results from the HRS-derived screening model allowed the development of a scored AUM site list for the Western AUM Region. As noted earlier, the scoring is not intended to identify actual risks, but is meant to provide a coarse screening of priority AUM sites for further investigation. The GIS approach facilitated a consistent and documented scoring process. The GIS cartographic tools also allowed flexible visualization of the data and analysis results.

Review of the Combined Pathway Scores (Table 4) and Figure 13 “Combined Pathway - Three Score Ranges” show that the highest scoring AUM sites occur in the Little Colorado River mining area of the Cameron Chapter (A&B No. 2 and A&B No. 3) and Coal-mine Canyon Chapter (Charles Huskon No. 1 and Jack Daniels Nos. 1, 4, and 5). All of these sites have been reclaimed by the NAMLRP. Since the primary HRS criteria are counts of structures and wells at specified distances from the AUMs, areas with high occurrences of homes and wells proximal to the AUM sites scored highest.

Conversely, remote AUM sites with sparse population and few wells scored low. This can be seen in the generally low scores for the AUM sites in the southwestern Coalmine Canyon, and southeastern and northern Bodaway/Gap Chapters (shown in green on Figure 13).

Martin Johnson No. 4 mine in the Bodaway/Gap Chapter (MAP-ID #5) is an example of an AUM site that scored moderately high (1,250) due to proximity of homes and wells. However, this AUM only had 37.5 tons of ore mined and produced 120 pounds of uranium and 23 pounds of vanadium. This is a significantly smaller production number compared to the Ramco No. 20 AUM (MAP-ID #94) that scored 260 but had 22,642 tons of ore mined with 99,226 pounds of uranium and 19,259 pounds of vanadium extracted. Production numbers are from Chenoweth, 1993.

As discussed under the METHODOLOGY section, the scores derived from this first stage of the model are only an indicator of potential risk, not actual risks. As such, it is only the first stage in the process of decision-making as to which sites are a priority for more information gathering. Since many of the mine features may have had their risk reduced by reclamation or removal, that information will also need to be included and evaluated.

RECOMMENDATIONS

The scores resulting from this CERCLA screening process identifies those sites EPA recommends to the Navajo Nation to "require further investigation." The level of subsequent investigation would depend on the status and current knowledge of the site. If there is no reliable data about the site, additional screening level field data would be advised to determine follow-up needs. If the mine site is already in EPA’s CERCLIS database, the next step would be to proceed with the Preliminary Assessment/Site Inspection phase of the HRS process to determine NPL candidates. If it is determined that a response action is required at a site, then characterization (detailed site studies) would be appropriate. Site specific characterization priorities should be established based on Navajo Nation priorities, AUM screening scores, resources, and site specific factors.

Screening assessments at mine sites commonly require evaluation of exposures from multiple sources and exposures via multiple pathways (EPA, 2000b). The modified HRS model used for this study was developed for the purpose of performing a coarse screening based on the presence of surface water drainages and the numbers of structures and wells proximal to AUM sites. Using existing GIS datasets, or by automating readily available data for the entire Navajo Nation, it may be possible to improve the analysis to better assess priority areas for further investigation. The following provides a list of existing or available datasets that could be used to develop additional factors that consider waste characteristics, likely transport pathways, and ecological targets.

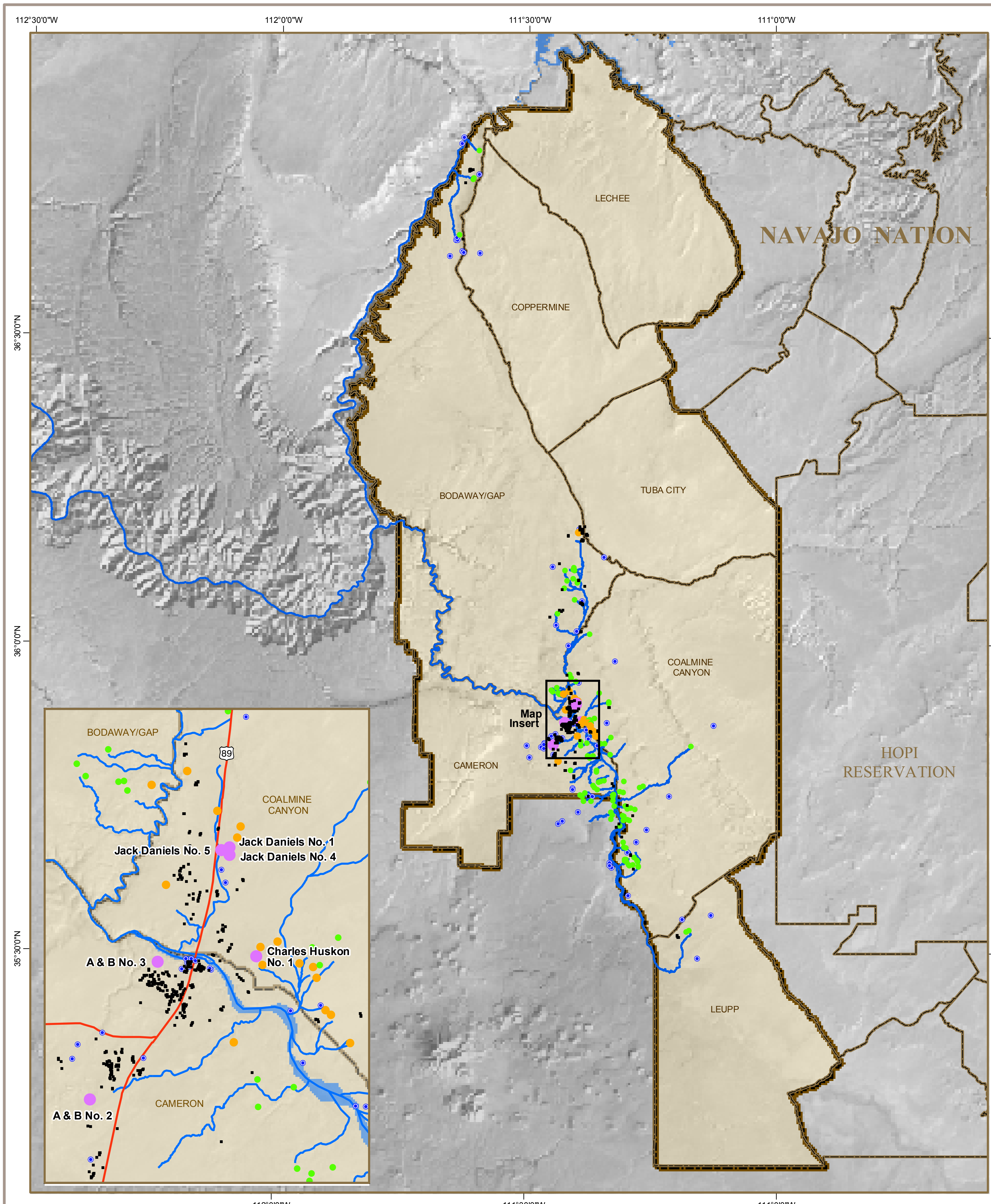
- HRS factors related to uranium mine waste characteristics:
  - AUM reclamation sites with associated unreclaimed mine debris piles
  - Reclaimed AUM sites compared to unreclaimed AUM sites (determined by NAMLRP to have insufficient risk for reclamation according to Office of Surface Mining Criteria)
  - Total uranium and/or vanadium production for each AUM
  - Bismuth-214 radiation data as an indicator of uranium concentrations
  - Host geologic formations for uranium ore
  - Water or stream sediment samples

- HRS factors related to pathways and likelihood of release:
  - Precipitation
  - Aquifer sensitivity
  - Intersections of surface water pathway buffers with downstream targets

- HRS factors related to targets:
  - Natural springs (undeveloped)
  - Sensitive habitats
  - Agricultural fields
  - Corrals and animal pens

EPA recommends a thorough review of available information prior to additional field investigations. Much of the available data and historic reports have already been provided to the NNEPA. A complete archive is also available in the Navajo Abandoned Uranium Mines Project files located in the EPA Region 9 Superfund Records Center, located in San Francisco, California. Emphasis on the following documents is recommended:

- Phase I
  - EPA Region 9 Superfund Records Center Archive Index
  - Maps, Documents, and Data (CD-ROM)
  - Project Atlas (CD-ROM)



ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Western AUM Region Screening Assessment Report

COMBINED PATHWAYS - THREE SCORE RANGES

Sources

Abandoned Uranium Mine (AUM) locations are primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by other sources. The Navajo Nation and Chapter boundaries are from the Navajo Lands Department. Hydrographic data for streams are from the U.S. Geological Survey (USGS) National Hydrographic Dataset. Structures were interpreted by TerraSpectra Geomatics. Wells are primarily from the Navajo Department of Water Resources and augmented by state water departments and USGS hydrographic datasets. The scores were calculated by TerraSpectra Geomatics using the modified Hazard Ranking System model developed by the U.S. Environmental Protection Agency, Region 9.

N W E S

0 20 Miles

Map Scale 1:700.000

Legend

Range of AUM Scores

- 10 - 499
- 500 - 1499
- 1500 - 5760

Targets

- Structures within 1 Mile of AUM
- Wells within 4 Miles of AUM
- Drainages 15 Miles Downstream from an AUM

Figure 13. Combined Pathways Map with Three Score Ranges.

- Phase II
  - EPA Region 9 Superfund Records Center Archive Index
  - DOE - Uranium Mining Summary Reports (Chenoweth)
  - State Mineralogy Department - Open File Reports
  - NAMLRP - Mine Reclamation Reports

The sites listed below in Tables 6 and 7 have come to EPA's attention due to elevated radionuclide activity in water samples (EPA, 2000a and Longsworth, 1994). As of December 8, 2003, the EPA Maximum Contaminant Level (MCL) for uranium is 30 micro-grams per liter (μg/L) or 20 pico-curies per liter (pCi/L)[1]. MCL is the maximum permissible level of a contaminant in water delivered to users of a public water system. Water samples from the following locations were sampled for Uranium^{234}, Uranium^{235} and Uranium^{238} and the summed total values were greater than 20 pCi/L (EPA, 2000a). The locations of these water samples with elevated uranium levels are displayed on Figure 14 "Water Sample Locations with Elevated Uranium."

USACE Sample ID	Sample Name	Sample Date	Total Uranium (pCi/L)
CT980729CMS004	Badger Spring	7/29/1998	22.06
CT980729CMS005	Tse To Baah Naali Spring	7/29/1998	23.33
CT980729CMS003	Tohachi Spring	7/29/1998	84.20
CT980811TCS001	Leechee Spring	8/11/1998	20.80
CT000120CMS009	Fivemile Wash Spring	1/20/2000	28.40
CT991130CAW007	Paddock Well	11/30/1999	46.40

Table 6. EPA Water Sample Locations With Elevated Uranium.

The USGS, in cooperation with the NAMLRP, began a study in 1991 to assess the chemical characteristics of six mines in the Cameron mining district (Longsworth, 1994). Water samples were also analyzed at existing wells and spring boxes (springs improved with concrete cisterns and hand pumps). The locations of these water samples with elevated uranium levels (greater than 20 pCi/L) are listed below and are also plotted on Figure 14 "Water Sample Locations with Elevated Uranium."

Sample Name	Sample Date	Total Uranium (pCi/L)
Clay Well Spring	11/05/1991	66.1
Arizona Inspection Station Well	12/19/1991	44.9

Table 7. USGS Water Sample Locations With Elevated Uranium.

These water sources cited were not sampled from Public Drinking Water Systems. The results for both studies were from one-time sampling events by EPA and the USGS and are not definitive with respect to attribution from anthropogenic versus naturally occurring sources. Water sampling was conducted prior to NAMLRP reclamation activity and current conditions may differ.

Collection and analysis of additional hydrologic data would be necessary to determine shallow ground-water flow characteristics and thus the implications of radionuclide mobilization near mines in the Cameron mining district (Longsworth, 1994).

NEXT STEPS

- NNEPA, NAMLRP and EPA should jointly review the report findings.
- NNEPA, NAMLRP, and EPA should collect post-reclamation water samples for water chemistry.
- NNEPA, NAMLRP, and EPA should develop a joint prioritization for the sites.
- EPA shall continue to support the Navajo Nation with additional assessment activities at NNEPA and shall address identified high priority areas of concern via the EPA Removal Program, at the request of the Navajo Nation.

[1] EPA, 2006. "List of Drinking Water Contaminants and MCL's" accessed on February 28, 2006 at URL http://www.epa.gov/safewater/mcl.html#mcls

REFERENCES

NOTE: Reference documents used in the preparation of this Screening Assessment Report were scanned. The electronic versions are included in the accompanying data package, with the exception of documents that are copyrighted, unpublished, draft, considered limited distribution, confidential, sensitive, or proprietary by the document providers. References that are followed by a source reference number (e.g., S02240306) are provided in electronic format and the source reference number is used as the document filename.

Blanchard, Paul J., 2002. “Assessments of Aquifer Sensitivity on Navajo Nation and Adjacent Lands and Ground-water Vulnerability to Pesticide Contamination on the Navajo Indian Irrigation Project, Arizona, New Mexico, and Utah.” U.S. Geological Survey Water Resources Investigations Report 02-4051, 27 p. (S01200301)

Chenoweth, William L., 2006. “E-mail Communication from William Chenoweth regarding Jack Daniels No. 3 and Max Johnson No. 4 Mines of the Cameron area” dated February 23, 2006. 4 p. (S02230601)

Chenoweth, William L., 2006. “Fax Communication from William Chenoweth regarding sending a Navajo Tribal Mining Department Cameron Area Mine Claims Map (S02180601), Mining Permit information for the Max Huskon, No. 1 and 2-7 claims, and copies of parts of S02180601 for the Max Huskon claims and the Martin Johnson claim” dated February 16, 2006. 4 p. (S02160601)

Chenoweth, William L., 1993. “Geology and Production History of the Uranium Deposits in the Cameron Area, Coconino County, Arizona.” Arizona Geological Survey, Contributed Report CR-93-B. 32 p. (S10100239)

Cooley, M. E., J. W. Harshbarger, J.P. Akers, and W.F. Hardt with a section on vegetation by O.N. Hicks, 1969. “Regional Hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah.” U.S. Geological Survey Professional Paper 521-A, prepared in cooperation with the Bureau of Indian Affairs and the Navajo Nation, 61 p. (S10290201)

Hendricks, Thane J., 2001. “An Aerial Radiological Survey of Abandoned Uranium Mines in the Navajo Nation - Surveys Conducted in Arizona, New Mexico, and Utah, Date of Surveys: 1994—1999.” DOE/NV/11718-602, Remote Sensing Laboratory operated by Bechtel Nevada for the U.S. Department of Energy, National Nuclear Security Administration, Las Vegas, Nevada. 24 p. (S03310309)

Longsworth, Steve A., 1994. “Geohydrology and Water Chemistry of Abandoned Uranium Mines and Radiochemistry of Spoil-Material Leachate, Monument Valley and Cameron Areas, Arizona and Utah.” U.S. Geological Survey, Water-Resources Investigations Report 93 - 4226, 43 p. (S02250302)

Navajo Abandoned Mine Lands Reclamation Program, 2004. “An ESRI Point Shapefile of NAMLRP Abandoned Non-Coal Mine Sites.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program.

Navajo Abandoned Mine Lands Reclamation Program, 2004. “An ESRI Polygon Shapefile of NAMLRP Abandoned Non-Coal Project Areas.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program.

Navajo Abandoned Mine Lands Reclamation Program, 2004. “E-mail Communication from Melvin H. Yazzie (NAMLRP) regarding Navajo AML GIS Database Review.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program. 4 p.

Navajo Abandoned Mine Lands Reclamation Program, 2002. “Western Navajo Plateau AML Reclamation Project, Technical Specifications.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program. May 2002. 90 p.

Navajo Abandoned Mine Lands Reclamation Program, 1990. “Report of Investigation, Cameron Problem Area, Cameron Uranium Mining District” Prepared October 1988, Revised January 1990. Prepared by Charles M Heaton, Tuba City Sub-Office. Obtained from the Navajo Abandoned Mine Lands Reclamation Department, Navajo Division of Natural Resources. 40 p.

Navajo Abandoned Mine Lands Reclamation Program, No Date. “A series of differentially corrected Trimble GPS files for the Cameron area, for the following project areas: NA-0104, NA-0110A, NA-0110B, NA-0111, NA-0121, NA-0124B, NA-0155A, NA-0155B, NA-0197A, NA-0197B, and NA-124C.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program.

Navajo Abandoned Mine Lands Reclamation Program, No Date. “A series of differentially corrected Trimble GPS files for the Cameron Reclamation Projects 1, 2, 3, and 4, for the following project areas: NA-0105A, NA-0105B, NA-0113, NA-0123, NA-0124A, NA-0125, NA-0127, NA-0128A, NA-0128B, NA-0129, NA-0130, NA-0131A, NA-0131B, NA-0134, NA-0135, NA-0136, NA-0137, NA-0138, NA-0139, NA-0141, NA-0148, NA-0149A, NA-0149B, NA-0149C, NA-0149D, NA-0153, NA-0154, NA-0163, NA-0166, NA-0172B, NA-0173, NA-0174, NA-0175, NA-0179, NA-0180, NA-0186, NA-0187, NA-0194, NA-0195, NA-0196A, NA-0196B, NA-0197, NA-0198, and NA-155A.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program.

Navajo Abandoned Mine Lands Reclamation Program, No Date. “A series of differentially corrected Trimble GPS files for the Cameron Reclamation Project 6, Monument Valley Reclamation Project 4, and two other areas, for the following project areas: NA-0102, NA-0103A, NA-0103B, NA-0106, NA-0107, NA-0108, NA-0109, NA-0184, NA-0216, NA-0217, NA-0219, NA-0220, NA-0221, NA-0222, NA-0234, CP6NA-0113, NA-0112, NA-0114AAB, NA0116, NA-0158A, NA-0158B, NA0159, NA0164, NA-0250, NA-0251, NA-0252, NA-0253, NA-0254, NA-0255, NA-0256, NA-0257, NA-0258, NA-0259, NA114AAA, NA114DAA, NA114DAB, and NA144AAC.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program.

Navajo Abandoned Mine Lands Reclamation Program, No Date. “Cameron 5 AML Reclamation Project, Technical Specifications. Obtained from the Navajo Abandoned Mine Lands Reclamation Program. 52 p.

Navajo Abandoned Mine Lands Reclamation Program, No Date. “Cameron, Arizona 1:62,500 U. S. Geological Survey Topographic Quadrangle, with Numbered Abandoned Mine Land Site Locations.” Navajo Abandoned Mine Lands Reclamation Program. (S03090489)

Navajo Abandoned Mine Lands Reclamation Program, No Date. “Cameron Project 4, Technical Specifications.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program. 86 p.

Navajo Abandoned Mine Lands Reclamation Program, 1997. “Contract Documents - Cameron 3 AML Project, Cameron, Arizona.” Obtained from the Navajo Abandoned Mine Lands Reclamation Program. Navajo Abandoned Mine Land Reclamation Program.

Navajo Abandoned Mine Lands Reclamation Program, No Date. “Mosaic of 1:24,000 U.S. Geological Survey Topographic Quadrangles, including Arizona Quadrangles Cameron NE, Cameron North, Cameron SE, Cameron South, Shadow Mountain Well with Numbered Abandoned Mine Land Site Locations and Project Numbers.” Navajo Abandoned Mine Lands Reclamation Program. (S03090490)

REFERENCES

Navajo Abandoned Mine Lands Reclamation Program, No Date. "Navajo Abandoned Mine Lands Reclamation Department, Cameron Project 1, Technical Specifications." Obtained from the Navajo Abandoned Mine Lands Reclamation Program. 38 p.

Navajo Abandoned Mine Lands Reclamation Program, No Date. "Navajo Abandoned Mine Lands Reclamation Department, Cameron Project 2, Technical Specifications." Obtained from the Navajo Abandoned Mine Lands Reclamation Program. 33 p.

Navajo Abandoned Mine Lands Reclamation Program, No Date. "Part of the Shadow Mountain Well, Arizona 1:24,000 U. S. Geological Survey Topographic Quadrangle, with Numbered Abandoned Mine Land Site Locations and Project Numbers." Navajo Abandoned Mine Lands Reclamation Program. (S03090481)

Navajo Abandoned Mine Lands Reclamation Program, No Date. "Part of the Wupatki NE, Arizona 1:24,000 U. S. Geological Survey Topographic Quadrangle, with Numbered Abandoned Mine Land Site Locations and Project Numbers." Navajo Abandoned Mine Lands Reclamation Program. (S03090479)

Navajo Nation Department of Water Resources, 2000. "Water Resource Development Strategy for the Navajo Nation." Strategic Plan dated July 17, 2000, 71p. (S12130214)

Navajo Tribal Mining Department, 1956. Claim Map, "Cameron Area, Navajo Reservation, Coconino County, Arizona." Navajo Tribal Mining Department. 1: 2000', July 17, 1956. (S02180601)

Navajo Tribal Mining Department, No Date. "Geology of the Cameron Area, Little Colorado Mining District, Coconino County, Arizona." Navajo Tribal Mining Department. (S02080605)

Office of Surface Mining Reclamation and Enforcement, 1999. "Annual Evaluation Report, for the Navajo Abandoned Mine Land Reclamation Program, Evaluation Year 1999 (October 1, 1998 through September 30, 1999)." Accessed on May 7, 2003 at URL *http://www.osmre.gov/oversight/navajo99.htm* (S05070313)

Scarborough, Robert A., 1981. "Radioactive Occurrences and Uranium Production in Arizona - Final Report." Arizona Bureau of Geology and Mineral Technology, Open File Report 81-1, 271 pp. (S09240202)

Schwarz, G. E. and Alexander, R. B., 1995. "State Soil Geographic (STATSGO) Data Base for the Conterminous United States." Metadata for USSOILS. Accessed on May 20, 2003 at URL *http://water.usgs.gov/GIS/metadata/usgswrd/ussoils.html.* (S08030303)

TerraSpectra Geomatics, 2004. "Project Meeting with NAMLRP in Page, Arizona." Letter to Glynn R. Alsup (USACE) dated June 2, 2004. TerraSpectra Geomatics. 11 p. (S06170401)

Unknown, 1956. "Plat of Yellow Jeep Mining Co., Mining Claims A&B, Navajo Indian Reservation - District No. 3, Coconino County, Arizona" Unknown. July 26, 1956. (S02080608)

U.S. Army Corps of Engineers, 2000. "U.S. Army Corps of Engineers IAG No. DW96955370-01-0 Abandoned Uranium Mines - Navajo Lands United States Environmental Protection Agency Region IX Data Quality Assurance Summary." Rev. 3. Obtained from U.S. Environmental Protection Agency, Region 9.

U.S. Atomic Energy Commission, 1956. "Claim Map East Black Falls Area, Navajo Reservation, Coconino Co., Ariz." U.S. Atomic Energy Commission. (S02080606)

U.S. Atomic Energy Commission, 1956. "Claim Map of Echo Cliffs Area, T 39 N R 7E, Coconino Co., Arizona" U.S. Atomic Energy Commission. (S02080607)

U.S. Environmental Protection Agency, 2006. "List of Drinking Water Contaminants and MCL's." Accessed February 28, 2006 at URL *http://www.epa.gov/safewater/mcl.html#mcls*

U.S. Environmental Protection Agency, 2004. "Abandoned Uranium Mines on the Navajo Nation, Arizona - EPA ID# NNN000906087, last updated July 16, 2004" Accessed November 23, 2004 at URL *http://yosemite.epa.gov/r9/sfund/overview.nsf/33951d3dc 70d 6ecd8825650f005dc903/d502c488f1841dc488256aee007c11bc?OpenDocument.*

U.S. Environmental Protection Agency, 2000a. "Abandoned Uranium Mines Project, Arizona, New Mexico, Utah—Navajo Lands, 1994-2000, Project Atlas." December, 2000. Obtained from U.S. Environmental Protection Agency, Region 9

U.S. Environmental Protection Agency, 2000b. "Abandoned Mine Site Characterization and Cleanup Handbook." EPA 910-B-00-001, U. S. Environmental Protection Agency Region 10, August, 2000, 130 p. (S02200302)

U.S. Environmental Protection Agency, 1999. "Navajo Uranium Mines King Tutt Mesa Study Area, Red Valley Chapter, Navajo Nation, Oak Spring, New Mexico, Draft Integrated Assessment." Site EPA ID Number: NND 986667434. Obtained from U.S. Environmental Protection Agency, Region 9.

U.S. Environmental Protection Agency, 1991. "Guidance for Performing Preliminary Assessments Under CERCLA." Office of Emergency and Remedial Response. EPA/540/G-91/013, Publication 9345.0-01A., 276 p. (S01230301)

U.S. Environmental Protection Agency, 1990. "40 CFR Part 300, Hazard Ranking System - Final Rule." Federal Register, Volume 55, No. 241, Friday, December 14, 1990. Obtained from U.S. Environmental Protection Agency, Region 9.

U.S. Geological Survey, 2001. "USGS Digital Orthophoto Quadrangles: Fact Sheet 057-01." Accessed on May 15, 2003 at URL *http://mac.usgs.gov/isb/pubs/factsheets/fs05701.html* (S05150301)

U.S. House of Representatives, 1993. "Deep Pockets: Taxpayer Liability for Environmental Contamination—An Investigative Report. Majority Staff Report of the Subcommittee on Oversight and Investigations of the Committee on Natural Resources of the U.S. House of Representatives, 103rd Congress." July 1993, U.S. Government Printing Office, ISBN 0-16-041168-8 (S12120221)

APPENDIX A - GIS DATASETS

STRUCTURES

SCREENING ASSESSMENT TARGETS

One of the data collection objectives for this study is to obtain existing data to support screening assessments. The primary purpose of screening assessments is to distinguish between abandoned uranium mine (AUM) sites that pose little or no threat to human health and the environment, including livestock and wildlife, and those sites that may require further investigation (EPA, 1991). AUM sites in the Western AUM Region are potential sources of hazardous materials. An important component of assessing potential threats is to identify whether there are any possible "targets", such as people or livestock, located near the sites or potentially impacted through some type of exposure. Some terms related to "targets" that are used throughout this document are provided here to help clarify the discussion.

Target

A target is defined as: "*a physical or environmental receptor that is within the target distance limit for a particular pathway* (ground water, surface water, soil, or air)" (EPA, 1991). Examples of potential targets include wells and surface water used for drinking water, livestock, fisheries, and sensitive environments, such as wetlands and riparian areas.

Target Distance Limit

A target distance limit is the maximum distance over which targets are evaluated. These distances vary by pathway (EPA, 1991). The target distance limits used in the HRS-derived model for the Western AUM Region screening assessment are:

- Soil Exposure Pathway 1-mile radius around the AUM site
- Air Pathway 1-mile radius around the AUM site
- Groundwater Pathway 4-mile radius around the AUM site
- Surface Water Pathway 15 miles downstream from the probable point of entry to surface water

Target Population

The target population is the human population associated with an AUM site and/or its targets. The target population consists of those people who use target wells or surface water for drinking water, eat food taken from impacted livestock or fisheries, or are regularly present on an AUM site or within target distance limits.

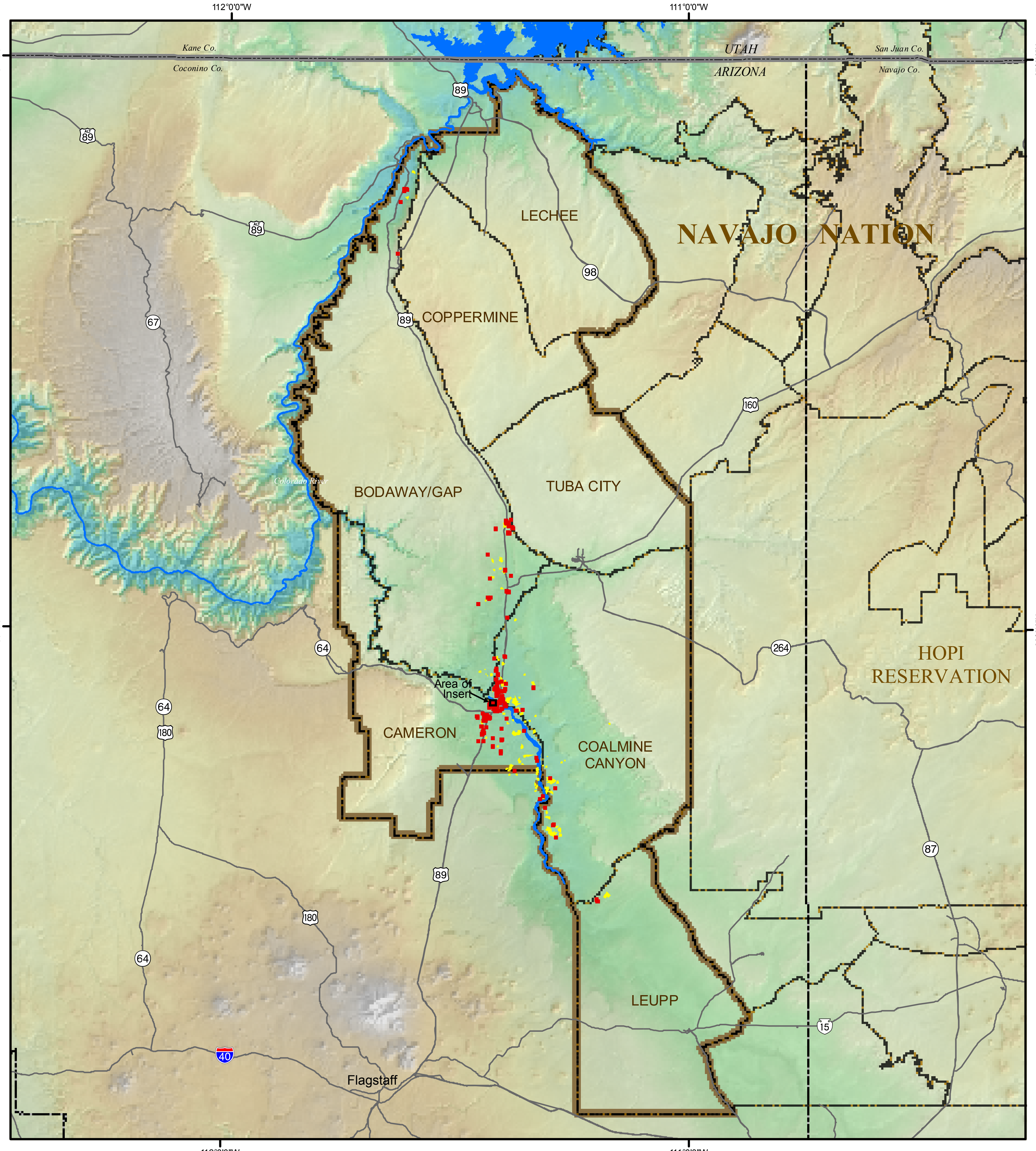
WESTERN AUM REGION

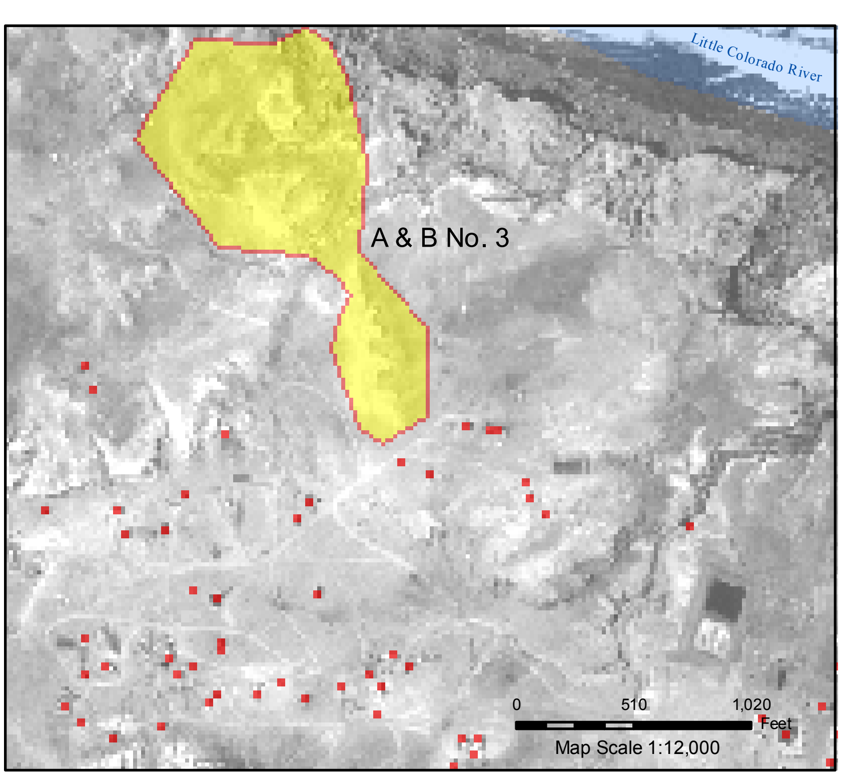
The Western AUM Region is sparsely populated throughout a land area of approximately 4,029 square miles (2,578,312 acres) in the Painted Desert region of the Navajo Nation. The 2000 Census estimated the total resident population for the entire region at 15,676. The summary table below provides the estimated land areas and estimated populations from the 1980, 1990, and 2000 Census for each of the 7 chapters within the Western AUM Region. This table was developed from Chapter Profile information obtained from the Chapter websites (e.g., www.cameron.nndes.org).

	Estimated Land Area (Acres)	Estimated Land Area (Sq. Miles)	1980 Census	1990 census	2000 census
BODAWAY/GAP	589,991	922	1,238	1,649	1,803
CAMERON	238,523	373	901	1,011	1,197
COALMINE CANYON	676,582	1,057	852	388	365
COPPERMINE	238,902	373	684	423	658
LECHEE	293,013	458	1,060	1,561	1,877
LEUPP	303,746	475	1,298	1,503	1,584
TUBA CITY	237,557	371	5,416	7,305	8,192
	2,578,312	**4,029**	**11,449**	**13,840**	**15,676**

For the purposes of assessing the potential target population, it is important to know where people live, work, go to school, and routinely gather. The locations of current residences were not readily available for the Western AUM Region. Existing USGS topographic maps include many buildings and other structures of interest. However, a majority of these maps are over 20 years old and still require conversion into a suitable GIS format for analysis. More recent USGS Digital Orthophoto Quarter Quadrangles (DOQQs) were available and were used as a basis to map buildings and other structures. The DOQQs were based on aerial photography acquired in 1992, 1997 and 1998. For a small number of features, the older topographic maps were used as an interpretation aid. The Navajo Tribal Utility Authority (NTUA) provided point locations for utility meters for the NTUA service areas within the Western AUM Region. The meter locations were collected using Global Positioning System (GPS). It was assumed that where there were water, gas, or electric meters there was probably some type of structure present. The NTUA meter data was very useful in mapping or verifying the location of probable structures constructed after 1998.

It was not possible to consistently distinguish residences from other types of structures using the DOQQ imagery and field verifications were not undertaken for this mapping effort. Residence-sized structures were mapped, including trailers. Some structures may be large sheds or other non-residential structures, and some may be seasonal residences and not occupied full-time. All of these structures, however, are indicative of locations where people might be present in the Western AUM Region. The structures that were mapped can be used as an indicator for the probable location of the target population. The map of structures within 1 mile of an AUM site is shown on the facing page.





Insert showing structures and AUM site A & B No. 3 overlain on the U.S. Geological Survey digital orthophoto quarter quadrangle (DOQQ) (Cameron South NE) for Cameron, Arizona.

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

Western AUM Region Screening Assessment Report

STRUCTURES

0 20 Miles

Map Scale 1:800,000

Legend

Structure Within 1 Mile of AUM

Abandoned Uranium Mine (AUM)

Sources

Structures within 1 mile of abandoned uranium mines were mapped by TerraSpectra Geomatics using USGS Digital Orthophoto Quarter Quadrangles (DOQQs), USGS topographic quadrangles, and utility meter locations provided by the Navajo Tribal Utility Authority (NTUA).

APPENDIX A - GIS DATASETS

ABANDONED URANIUM MINES

URANIUM MINING

Although outcrops of radioactive minerals exist throughout much of the Navajo Nation, the areas where ore was extracted and deposited in mine waste piles exhibits higher radiation levels than most undisturbed natural areas (OSM, 1999). The excavation of uranium ore bodies is associated with hazards due to both physical hazards and radiation exposure. Radiation is particularly hazardous because it cannot be seen or detected without the aid of specialized equipment. The result is that radiation exposure or contamination is not readily apparent. Hazards associated with abandoned uranium mines (AUMs) include open portals, adits, vertical openings, inclines and declines, radioactive waste piles, radioactive dust, rim cuts, high walls, and embankments (OSM, 1999).

The main mining area in the Western AUM Region is centered around the settlement of Cameron and forms a curved belt that is approximately 2 miles wide in a 6-mile stretch north of Cameron along U.S. Highway 89 and five miles wide in an 18-mile stretch southeast of Cameron along the Little Colorado River. A few small outlier properties are found as far north as Navajo Springs along the Echo Cliffs, as far south as the Grand Falls of the Little Colorado River, and as far east as Ward Terrace (Chenoweth, 1993). Ward Terrace is a broad sloping terrace along the northeast and east edge of the mining district and was formed from erosion of sandstone and limestone. Between Ward Terrace and the Little Colorado River are small hummocky hills and gently sloping topography formed from erosion of less resistant rocks. This area is part of the Painted Desert (Longsworth, 1994).

Uranium mining in the Western AUM Region was active between 1951 through 1963. Most of the mining was from open pits, which ranged in size from a shallow trench containing a single fossil log to pits as deep as 130 feet. During this period 100 separate properties produced 289,248 tons of ore containing 1,211,812 pounds of U_3O_8. The bulk of the ore (98%) was mined from the Petrified Forest Member of the Chinle Formation. Properties in the Shinarump Member of the Chinle Formation produced about 2% of the uranium. Two properties in the Kayenta Formation and a single mine in a breccia pipe (more than 1 mile off the Navajo Nation) produced the remaining uranium. Mining in the Western AUM Region diminished in the early 1960's when operators could not maintain sufficient volume of ore to continue economic mining operations (Chenoweth, 1993).

RECLAMATION

Since May 1990, the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) has worked to reclaim eligible AUMs on the Navajo Nation. A scheme for prioritizing non-coal mine sites was established, with Priority 1 sites exhibiting extreme physical hazards, easy access, and danger to life and property. Priority 2 and 3 sites have less physical danger, more difficult access, and lower visitation. Inventories and priority assessments of AUMs were conducted by the NAMLRP during the period August 1988 through October 1990. NAMLRP compiled information about each reported occurrence of past uranium activity on the Navajo Nation. Field inventories and investigations were then conducted to develop a comprehensive inventory of the AUM sites.

AUM FEATURE LOCATIONS

Mine feature locations (e.g., portals, shafts, rim strips, prospects, waste piles) were provided by the NAMLRP on 7.5 minute USGS topographic maps and coded by mine feature type. These maps were georeferenced and a GIS point dataset was created. There are 100 mapped point mining features associated with the AUMs in the Western AUM Region. The mining features are comprised of Vertical Shafts (2), Portals (3), Rim Strips and Pits (84), and Prospects (11) An example of AUM sites and features in the Western AUM Region is shown on the facing map figure.

AUM BOUNDARIES

NAMLRP provided maps and coordinates from Global Positioning System (GPS) measurements for the location of AUM Reclamation Project Areas. Of the 86 NAMLRP AUM reclamation project areas, 83 were mapped using GPS in the Western AUM Region. NAMLRP project areas generally included groups of mine features that were associated with one or more mining operations. They encompass the mapped mine features, smaller unmapped features of a mining operation, and a buffer around the mining operations by about 50 feet. These NAMLRP project polygons provide excellent mine operation locations and extents. However, in some cases, it was possible to further refine the AUM boundaries by including airborne radiological anomalies, and/or photo-interpreted mine-related surface disturbances.

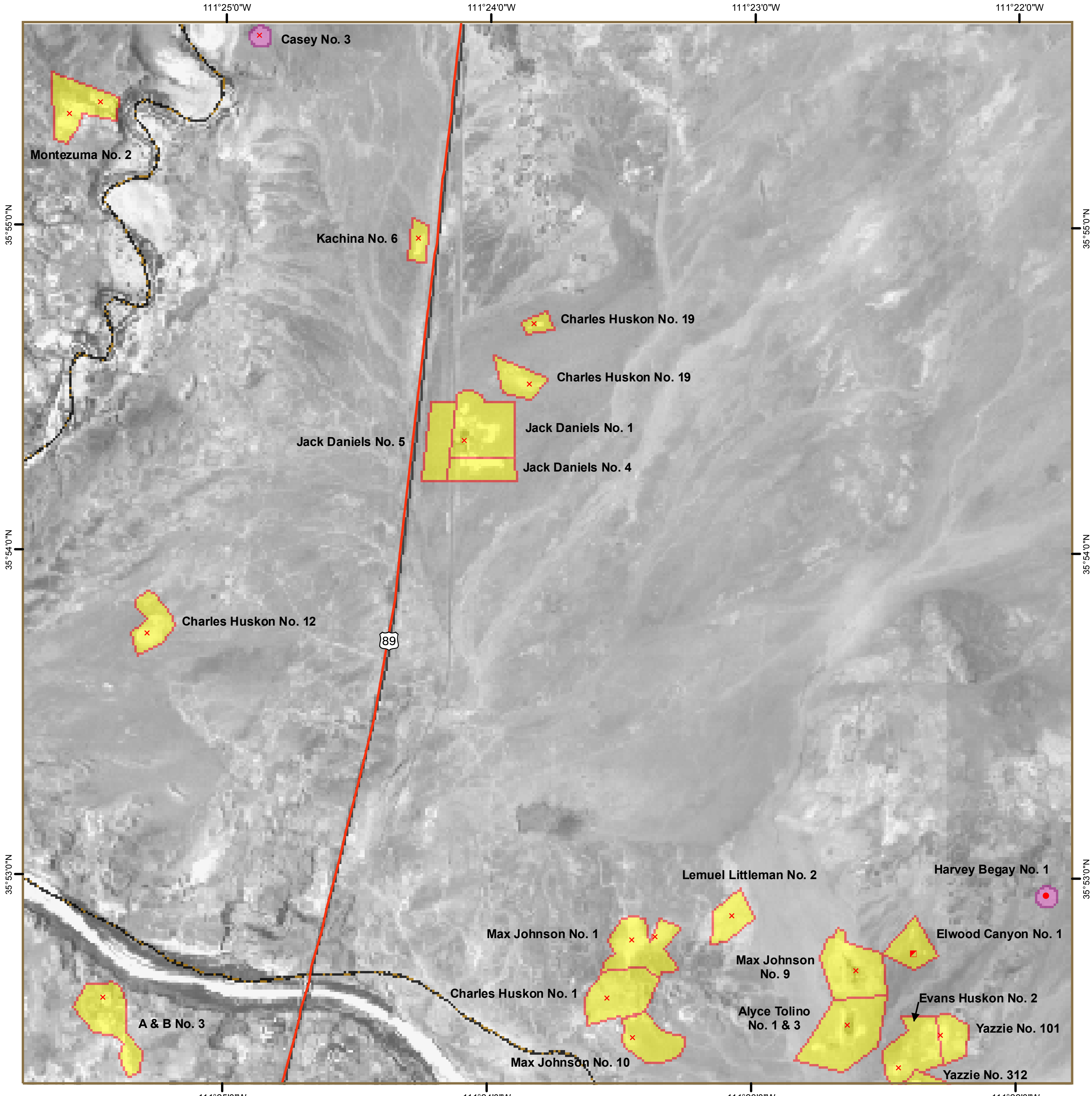
Some NAMLRP project boundaries were modified based on aerial radiation data collected in 1999 by the U.S. Department of Energy Aerial Measuring System (Hendricks, 2001). USGS DOQQs were also inspected around each NAMLRP project. Boundaries were extended where photo-interpreted mine related disturbances could be mapped outside and adjacent to the NAMLRP project. Some NAMLRP projects encompassed more than one mine. In these cases, NAMLRP projects were split into two or more polygons to enable the separate representation of AUMs. All of the modifications to the NAMLRP project boundaries were documented in the metadata, and resulted in a new GIS dataset of AUM boundaries.

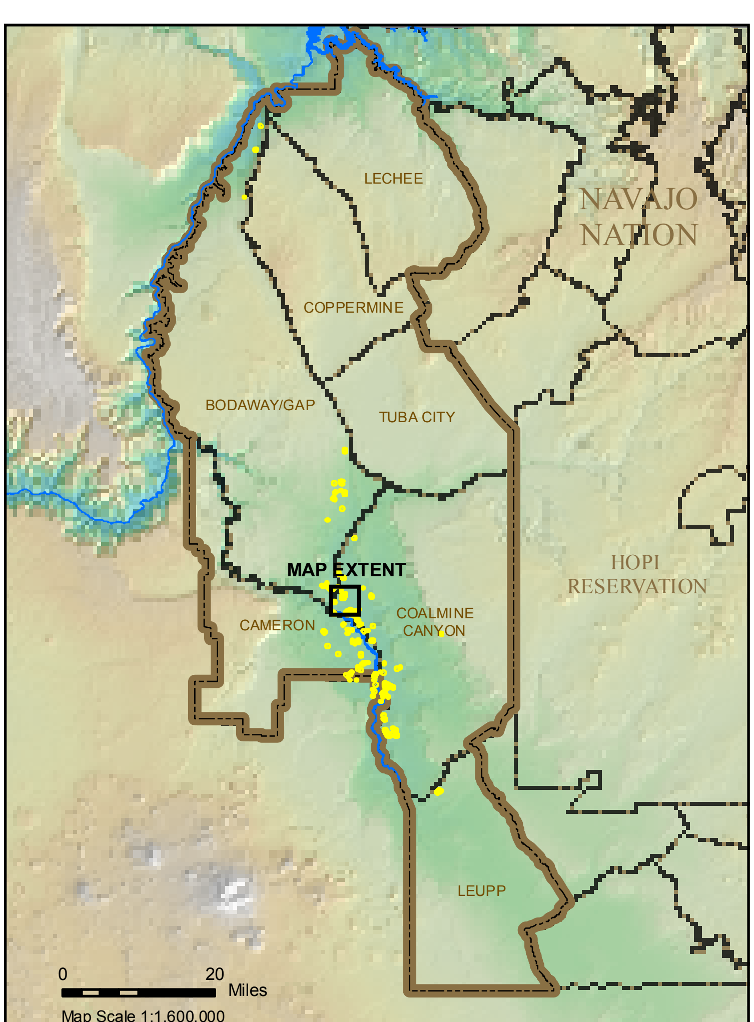
AUM polygons were also generated for mine features that were not included in the NAMLRP reclamation projects. These AUM polygons were generated by creating a 200 foot buffer around the feature.

Several AUMs were added to the AUM GIS dataset from sources other than NAMLRP. Locations for 20 AUMs were added from reports and documents provided by William Chenoweth and 4 AUMs were added from Navajo Tribal Mining Department claim maps. There are 108 AUMs mapped for the Western AUM Region, and 124 AUM polygons in the GIS dataset. There are more polygons than mines because in some cases a mine had more than one associated area of disturbance.

There was no significant underground mining in the Western AUM Region. However, it is known that at the base of some large pits (e.g., Ramco 20 and 21) adits were dug into pit walls in order to follow minor ore trends (Chenoweth, 1993). These minor underground workings were not mapped or entered into the GIS database.

The AUM polygon boundaries represent the extents of the surface features associated with the AUMs and they were used as the basis for generating buffers for the Soil, Air, Surface Water and Groundwater Pathway analyses.





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ABANDONED URANIUM MINES (AUM)

N
W E
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0 1 Miles

Map Scale 1:25,000

Legend

- Reclaimed AUM Sites
- Unreclaimed AUM Sites
- Portal (Adit / Incline)
- Prospect
- Rim Strip / Pit
- Vertical Shaft

Sources

Locations for the AUMs were primarily from the Navajo Abandoned Mine Lands Reclamation Program (NAMLRP) and augmented by other sources. A primary source was Chenoweth, 1993. Designations of the type of mine feature (e.g. portal, prospect, shaft) were also provided by NAMLRP.

NAMLRP determined that some AUM sites were not feasible for reclamation. These unreclaimed mine features were buffered by two hundred feet in order to create Unreclaimed AUM Sites.

Base images are Cameron North SE and Cameron NE SW Digital Orthophoto Quarter Quadrangles (DOQQ) from 1997 aerial photography.

WATER SOURCES AND DRAINAGES

WATER SOURCES

Proximity to water sources is a significant consideration when performing a screening assessment. The closer a well or developed spring is located to an AUM, the higher the likelihood that it may be exposed to hazardous substances. The following provides a discussion about water resource management on the Navajo Nation and information about the water sources within the Western AUM Region.

The rivers, washes, and aquifers constitute the water of the Navajo Nation which are under the jurisdiction of the Navajo Nation Water Code and are subject to the Navajo Nation's water management. The Navajo Department of Water Resources (NDWR) reported in July 2000 that the total domestic water consumption on the reservation was approximately 12,000 acre-feet annually. Per capita water use on the reservation ranges from between 10 and 100 gallons per day depending upon the availability and accessibility of the water supply. By comparison, the average per capita use for neighboring non-Indian communities in Arizona is 206 gallons per day. Approximately 40 percent of the Navajo population on the reservation is without tap water in their homes, and are required to haul water long distances to provide water for their homes. Water haulers sometimes rely on non-potable water sources, such as stock tanks, for potable purposes (NDWR, 2000).

Groundwater is the most heavily used and dependable water source for the Navajo Nation. The NDWR Water Management Branch maintains water resource databases and provides hydrologic information needed to serve the interests of the Navajo people. The Water Management Branch maintains an extensive database of groundwater well information, which is the primary data resource for groundwater information on the Navajo Nation. The database includes over 8,000 well records for the entire Navajo Nation. Data is provided on new wells based on the information documented in the well-drilling permits and the water-use permits. All locations for water sources in the NDWR well database were used for the screening analysis (oil wells and possible oil wells were excluded).

The map figure on the facing page shows the locations of wells and developed springs or water sources within 4 miles of an AUM for the Western AUM Region. The well locations are from the NDWR well database, and augmented using Arizona Department of Water Resources, National Hydrography Database, Geographic Names Information System, U.S. Army Corps of Engineers water sample locations, USGS Groundwater Site Investigations database, and USGS topographic maps and digital orthophoto quarter quadrangles.

DRAINAGES

Drainages are important to surface water pathway screening assessments. This factor involves assessing whether potential drainage pathways exist for the transport of hazardous substances to migrate via surface water, and if so, whether any targets (intakes supplying drinking water, fisheries, or sensitive environments) are likely to be exposed to the hazardous substance. In areas, such as the Western AUM Region, where mean annual precipitation ranges from 6 to 9 inches per year, intermittently-flowing waters qualify as surface water.

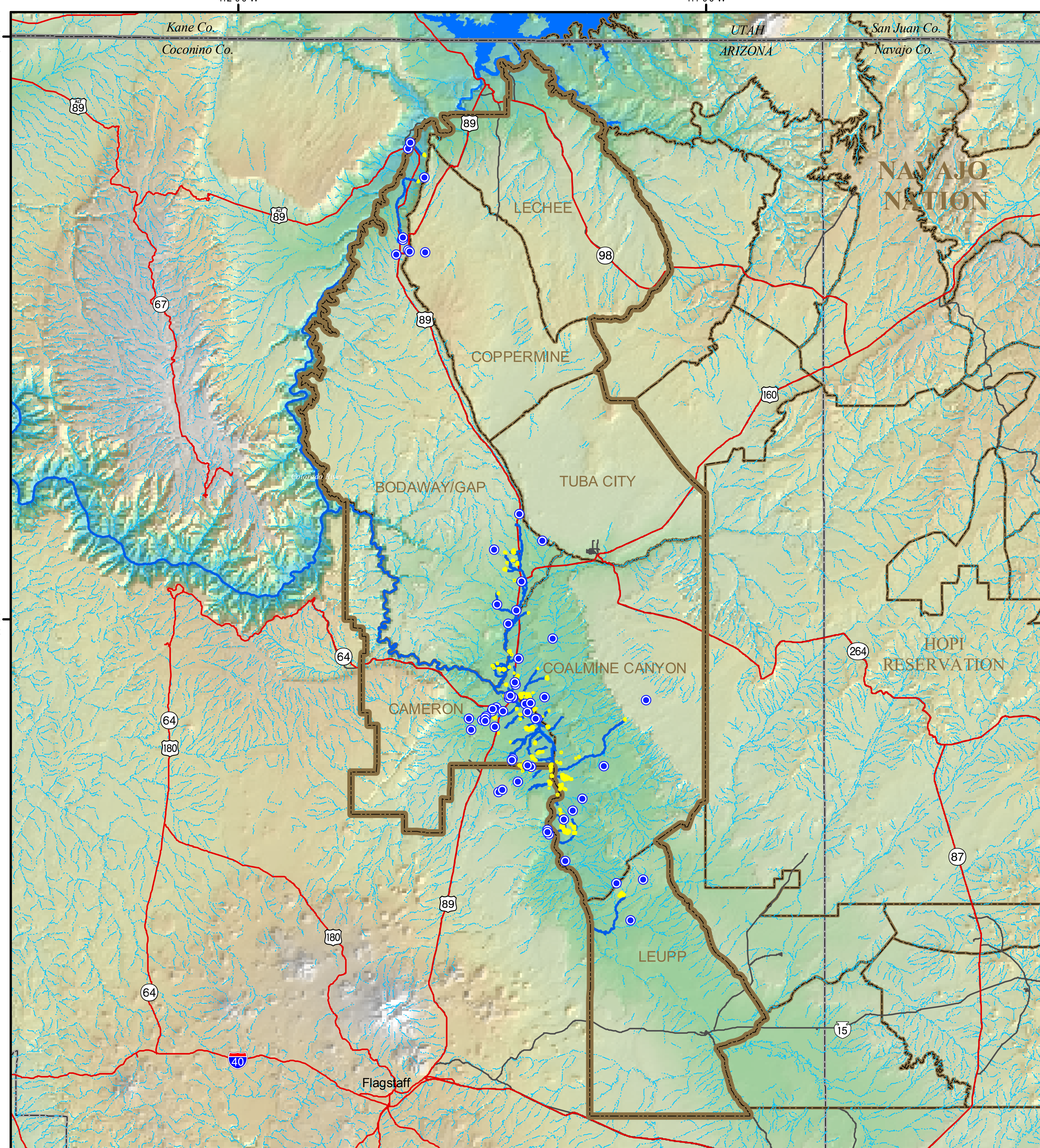
Erosion is a concern for abandoned uranium mine sites because of the mine wastes. Major sources of erosion/sediment loadings at mining sites include waste rock and overburden piles, haul and access roads, exploration areas, and reclamation areas. The main factors influencing erosion include rainfall/snowmelt runoff, soil infiltration rate, soil texture and structure, vegetative cover, slope length, and erosion control practices. Erosion may cause loading of sediments to nearby drainages, especially during severe storm events and high snowmelt periods. Hazardous constituents (e.g., radionuclides and heavy metals) associated with discharges from mining operations may be found at elevated levels in sediments (EPA, 2000b).

The majority of runoff on the Navajo Nation is to the Colorado River, the master stream of the Colorado Plateau. Most of the Navajo Nation is drained by two principal tributary streams, the San Juan and the Little Colorado Rivers. The Colorado and San Juan are the only major perennial streams, all other streams are either ephemeral or intermittent (Cooley et al., 1969). Perennial streams have visible water flowing above the streambed year-round. Intermittent streams flow water part of the time in most years and have a defined stream channel. Ephemeral streams flow water in response to heavy rainfall events and do not have a defined stream channel. Stream flow in the intermittent channels is also dependent on storm events. Differences in rainfall patterns cause stream flow to be extremely variable. Approximately one-half of the annual precipitation occurs from July through October, generally in the form of localized, short-duration, high-intensity thunderstorms. These storms may create large flows, which are commonly of limited duration and extent.

The type of soil, and the amount and type of vegetation, have a significant effect on the amount of precipitation that becomes surface runoff. Runoff of the streams tributary to the Little Colorado River tends to be sporadic and is controlled largely by three factors: interception; transmission losses; and effect of convectional and frontal storm systems.

The Western AUM Region lies within the Painted Desert hydrogeologic subdivision of the Navajo Nation, which is part of the Black Mesa Hydrologic Basin. Regional groundwater flow in the Western AUM Region is toward the Little Colorado River (Cooley et al., 1969). The region is drained by the Moenkopi Wash and the Little Colorado River. The Moenkopi Wash drains the northern part of the Cameron mining district (also known as the Little Colorado Mining District) and is the largest tributary of the Little Colorado River within the district, flowing into the Little Colorado River approximately 3 miles northwest of Cameron. The Little Colorado River channel is broad and shallow in the southeastern part of the district but forms a more narrow, steep canyon downstream near Cameron. The river flows intermittently northwestward across the district and joins the Colorado River in the Grand Canyon (Longsworth, 1994).

The surface water stream drainages in the Western AUM Region are shown on the map figure on the facing page.



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WATER SOURCES AND DRAINAGES

0 20 Miles

Map Scale 1:800,000

Legend

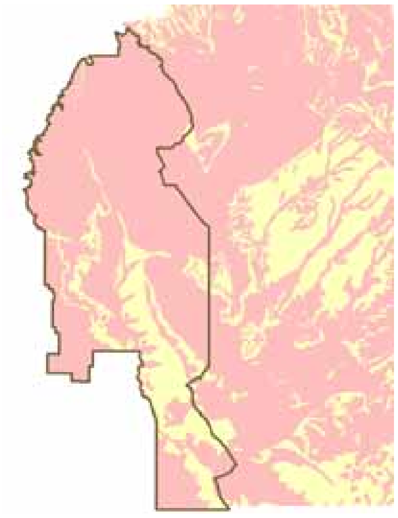
- Wells Within 4 Miles of an AUM
- Intermittent Stream
- Perennial Stream
- Water Pathway Downstream from AUM

Sources

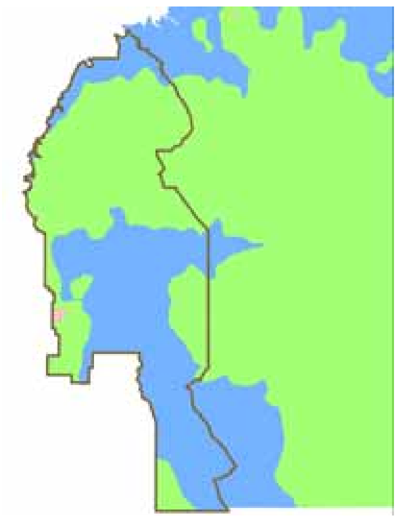
Water sources are primarily from the Navajo Department of Water Rsources (NDWR) and augmented with data from state water departments and U.S. Geological Survey (USGS). The water sources include wells and developed springs. The perennial and intermittent streams are from the National Hydrography Dataset (NHD).

Tank 3K-312 in the Coalmine Canyon Chapter.

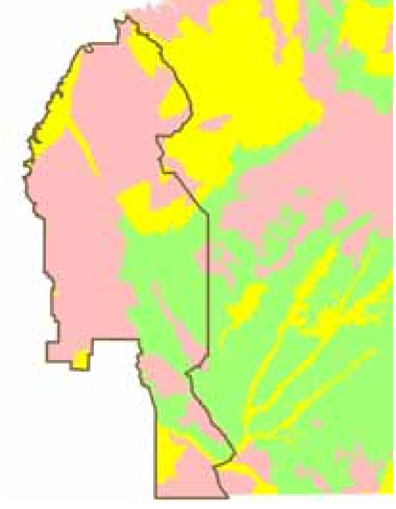
AQUIFER SENSITIVITY



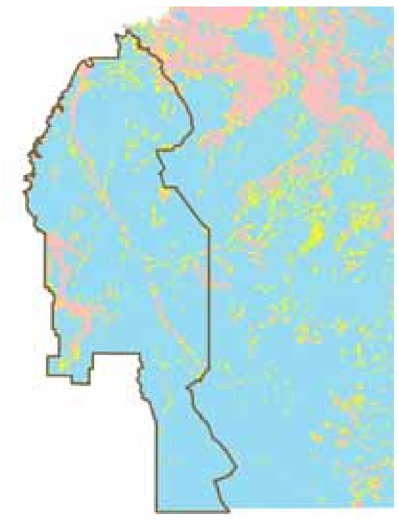
Geology



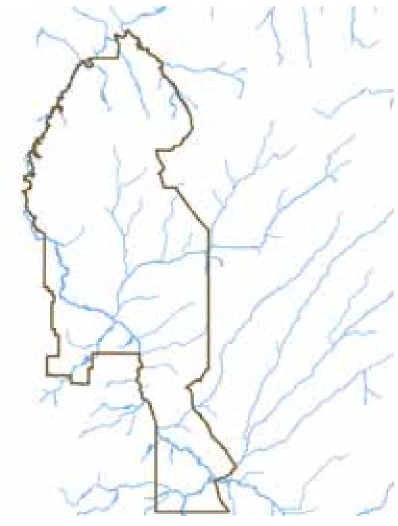
Precipitation



Soil Properties



Slope of the Land Surface



Fourth-order Stream Courses

Blanchard (2002) cites the definition of aquifer sensitivity as "the relative ease with which a contaminant applied on or near a land surface can migrate to the aquifer of interest. Aquifer sensitivity is a function of the intrinsic characteristics of the geological materials, and the overlying unsaturated zone."

Blanchard's model was developed using broad physical characteristics to describe aquifer sensitivity to surface and near surface contaminants. The model can be applied to the movement of radionuclides and heavy metals to the underlying groundwater. The aquifer sensitivity model complements the screening assessment presented in this report, but was not used in the scoring model.

The factors used in the Blanchard model include geology, precipitation, soil properties, slope of the land surface and stream courses. Blanchard stated that the largest limitation on this method was inadequate information on depth to the uppermost aquifer. For the Western AUM Region, each of these factors is shown at the left. The following describes the inputs used in Blanchard's (2002) assessment.

The geology was developed from Cooley et al. (1969). It identifies where consolidated rocks are recharged and unconsolidated deposits are at the surface (pink on the geology map at left) and facilitate aquifer contamination. Geology acts as a surrogate for impact of the vadose or unsaturated zone. Yellow identifies areas that do not contribute to recharge.

Water provides the solvent in which contaminants are transported from the land surface to the aquifers. Precipitation is the surrogate for recharge where greater precipitation results in greater potential for contaminants to infiltrate the land surface. In the precipitation map at left, pink indicates high precipitation and most potential to facilitate contamination. Green indicates intermediate, and blue indicates least precipitation and potential to facilitate aquifer contamination.

Several soil properties contribute to the potential to facilitate aquifer contamination, including: texture, infiltration rate, drainage, and organic content. These properties were developed from a modified version (Schwartz and Alexander, 1995) of the STATSGO, or State Soil Geographic database created by the U.S. Department of Agriculture, National Resources Conservation Service. Blanchard further describes that finely textured soil reduces the rate at which water and contaminants move through the soil (low hydraulic conductivity). High infiltration rates indicate a soil that permits a high volume of water to enter from the land surface. Lower drainage rates indicate a higher resident time. Soil organic content affects microbial activity and sorption. Blanchard found that soils on the Navajo Nation had an organic content of less than 2 percent, indicating minimal microbial activity and sorption. With no relative difference across the Navajo Nation, organic content was not used. A soil with a larger potential to facilitate aquifer contamination (green on the soil properties map at left) is coarse-grained, has a high infiltration rate, is well drained, and has a low organic content. Yellow indicates areas with intermediate potential, and a lower potential soil (pink on the soil map at left) is fine-grained, has a low infiltration rate, is poorly drained, and has a high organic content.

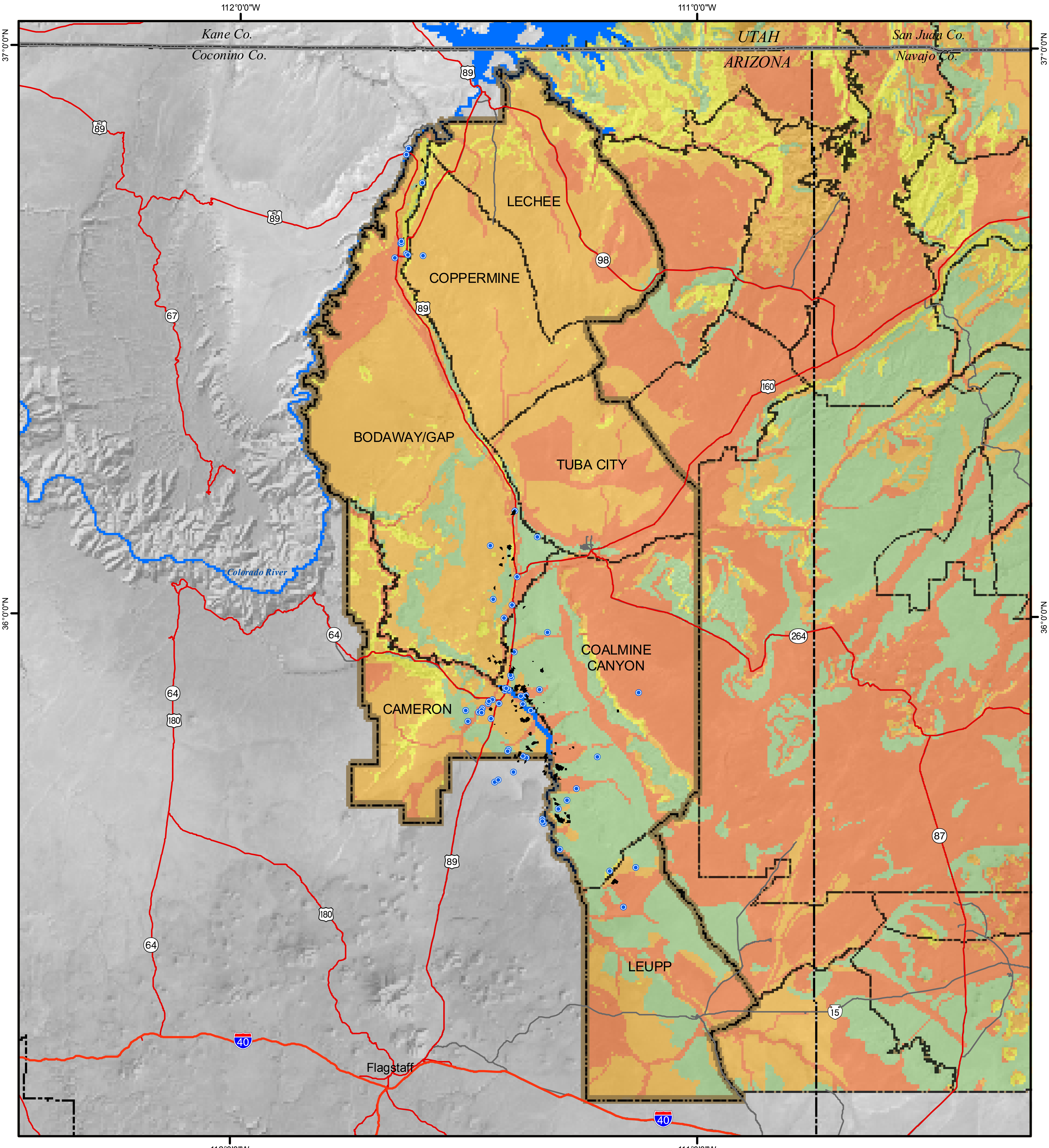
Land surface slope affects the ability of precipitation to infiltrate soil. Slopes less than 6 degrees (blue in the slope map at left) permit precipitation to stay in contact longer with the soil, thereby increasing infiltration of water into the land surface. Conversely, slopes of 6 to 12 degrees (intermediate slopes shown in yellow) and steep slopes greater than 6 degrees (pink in the slope map at left) minimize infiltration because water runs off quickly.

Blanchard developed buffered fourth-order and higher stream courses from USGS DEM's. Stream courses, wherever they occurred, were assigned the greatest potential to facilitate contamination because they concentrate runoff and have flat slopes. Floodplain and terrace soils are also composed of materials that highly facilitate contamination.

Blanchard summed the assigned numeric scores for each of the precipitation, soil properties, and slope layers and multiplied by the geology score (1 for facilitates contamination and 0 for does not facilitate contamination).

A final aquifer sensitivity map was developed from these scores and is shown on the map figure on the facing page. The highest scores represent the most potential for contamination category, low scores are in the least potential, and intermediate scores produce intermediate potential. The insignificant category represents areas where the geology score was zero or were not areas of recharge to bedrock aquifers and/or areas of unconsolidated deposits (stream alluvial deposits).

Aquifer sensitivity was not incorporated into the screening assessment scoring model used in this report. It is presented here to illustrate the concept of how this type of geospatial information could be used to develop additional screening criteria.



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AQUIFER SENSITIVITY

Sources

The aquifer sensitivity was developed and provided by Paul Blanchard (2002) U.S. Geological Survey, Water Resources Division in Albuquerque, New Mexico. The data are from a Water-Resources Investigations Report 02-4051 titled "Assessments of Aquifer Sensitivity on Navajo Nation and Adjacent Lands and Ground-Water Vulnerability to Pesticide Contamination on the Navajo Indian Irrigation Project, Arizona, New Mexico, and Utah."

Aquifer sensitivity, which is shown above on a shaded relief image, refers to the potential to contaminate the ground water - ranging from an "insignficant" to the "most" potential. This was determined by an investigation of the geology, precipitation, soils, slope, and stream courses of the area.

0 20 Miles

Map Scale 1:800,000

Legend

Aquifer Sensitivity Class

- 0 - Insignificant Potential
- 1 - Least Potential
- 2 - Intermediate Potential
- 3 - Most Potential
- Wells
- Abandoned Uranium Mines

APPENDIX A - GIS DATASETS

AERIAL RADIATION SURVEYS

Aerial radiation surveys were flown in October 1994 by the U.S. Department of Energy's (DOE) Remote Sensing Laboratory to evaluate whether the remote sensing technology could provide useful information for locating and characterizing AUMs. The surveys were flown using a helicopter-based acquisition platform equipped with custom 2 x 4 x 16 inch log type thallium-activated sodium iodide (NaI[Tl]) scintillation detectors. The BO-105 helicopter was configured with a total of 8 log detectors. Aircraft position was established using a real-time differential global positioning system (GPS) and a radar altimeter. Gamma rays detected by the NaI(Tl) detectors were digitized and sorted in the data acquisition system to produce second-by-second records of the gamma ray spectrum. Because every radioactive material has a unique set of gamma rays, a spectrum can be used to identify and separate the sources of the detected gamma radiation.

The survey was flown at an altitude above the terrain of 150 feet, resulting in a nominal footprint of 300 feet, and a line spacing of 250 feet. Radiation sensor measurements were integrated and recorded at one-second intervals. Each measurement provided an average radiation level for the entire ground sample area. This means the data does not pinpoint the radiation levels within the ground sample area, (i.e., the 300 feet diameter footprint under the helicopter). For each ground sample area, the radiation source could be evenly distributed or it could be made up of a combination of radiation sources, such as a higher-level mine waste debris pile placed on soil that had lower regional radiation levels. Obtaining finer detail measurements of an individual radiation source requires additional ground-based measurements.

The DOE Aerial Measuring System (AMS) survey capability was subsequently used to measure and map radiation sources within known uranium mining areas across the Navajo Nation. Helicopter surveys in the Bodaway East, Bodaway West, Cameron, Cedar Wash, Coalmine Chapter, Coalmine Mesa A, Coalmine Mesa B, Coalmine Mesa C and Tuba City survey areas were conducted in 1997. These 1997 surveys were flown at a line spacing of 300 feet (Hendricks, 2001).

The table below provides summary information for the aerial radiation surveys that were flown in the Western AUM Region.

Aerial Radiation Surveys in the Western AUM Region - Summary Information

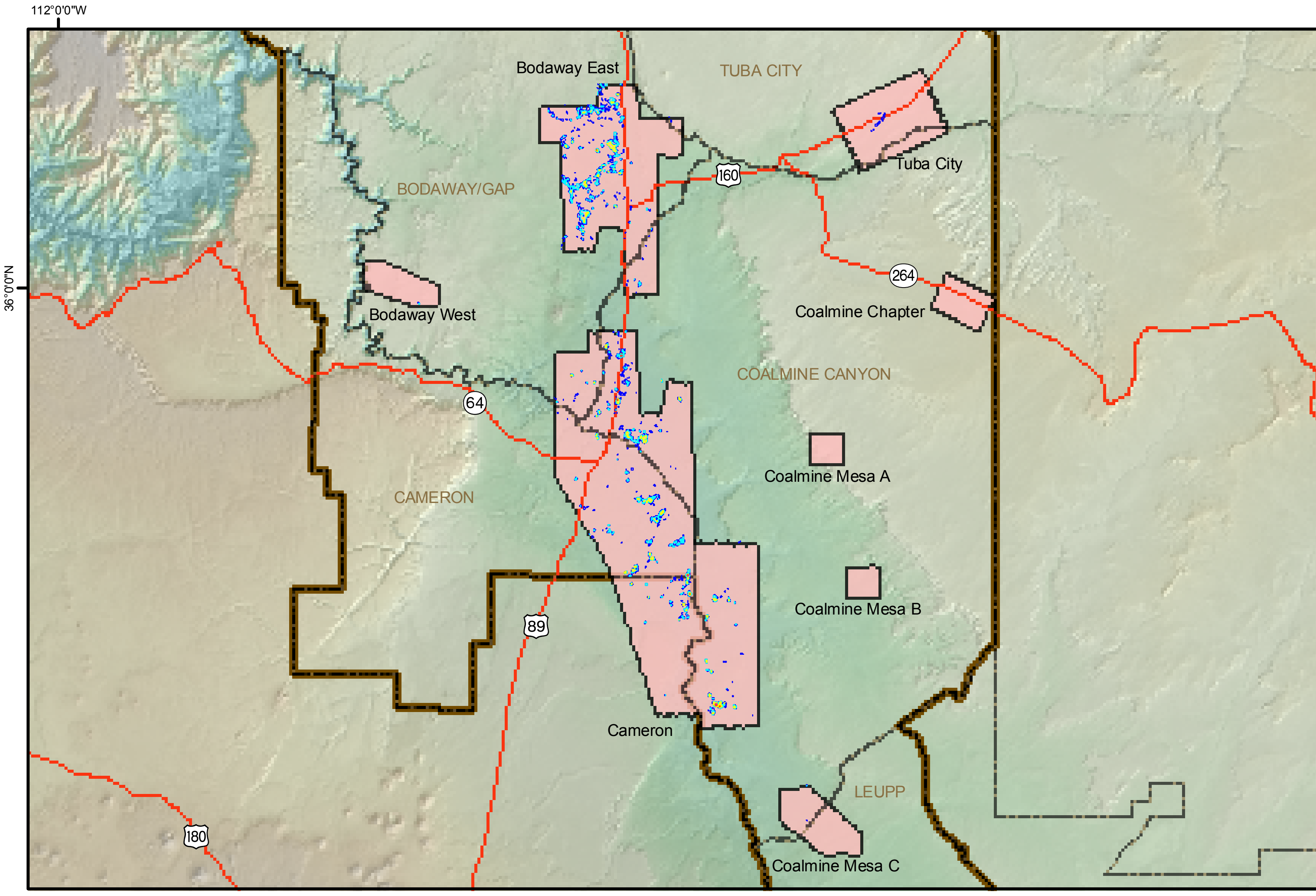
Area Name	Sub Area Name	Survey Start End	Survey Areas (sq. miles)	Terrestrial Exposure Rate in uR/hr Does not include cosmic which ranges from 5.1 @ 4000 ft to 9.7 @ 9000 ft elevation				Total # Survey Samples	Excess Bismuth Greater than 80 cps (Approx 3.5 uR/hr)		Notes
				avg	dev	min	max		# of samples	Approx acres	
Cameron	Bodaway East	09/23/97 09/25/97	60.62	9.21	3.04	2.4	47	40,868	2,732	2589.3	2,4
	Bodaway West	09/10/97 09/10/97	7.48	5.65	1.69	2.42	11.7	5,203	8	7.4	2,4
	Cameron	09/25/97 10/03/97	166.72	8.26	2.41	2.43	66.66	110,803	2,734	2632.8	2,4
	Cedar Wash	09/09/97 09/10/97	3.58	5.68	1.16	2.54	9.5	2,595	0	0.0	2,4
	Coalmine Chapter	09/11/97	7.52	4.56	0.58	3.32	7.77	4,984	0	0.0	2,4
	Coalmine Mesa A	09/10/97	3.80	4.75	2.23	2.3	11.22	2,658	0	0.0	2,4
	Coalmine Mesa B	09/23/97 09/24/97	3.69	6.9	1.01	4.69	10.19	2,678	0	0.0	2,4
	Coalmine Mesa C	09/11/97 09/23/97	12.88	6.43	1.04	2.06	15.33	8,768	6	5.6	2,4
	Tuba City	09/11/97 09/12/97	24.78	3.42	1.3	1.57	10.22	16,339	58	56.3	2,4

Key for Notes: 2 = B412 helicopter with 12 (2x4x16) gamma detectors
4 = 300 foot line space

The radiation data that were collected for the Western AUM Region are provided in two forms: gross count and excess Bismuth^{214}. Bismuth^{214} radiation is indicative of the presence of uranium, making it a good indicator of old mines and mining related activities. The Bismuth^{214} response, rather than a uranium response, is used because its unique photo peak can be readily distinguished from other radiation. The aerial survey areas and the Bismuth^{214} radiation contours are shown in the top map figure on the facing page. These aerial radiation contours were used as an aid in locating and defining the surface extents of abandoned uranium mines.

Gross count measures total terrestrial gamma activity, without considering its source, much like a Geiger counter. Aerial gross count data documents the wide range of radioactivity present, even in areas not associated with uranium mining activities. The gross count radiation contours are shown on the bottom map figure on the facing page.

For a more comprehensive explanation of the acquisition and processing methods used for the aerial measurements of radiation, a report has been developed by the DOE's Remote Sensing Laboratory titled "An Aerial Radiological Survey of Abandoned Uranium Mines in the Navajo Nation" (Hendricks, 2001).



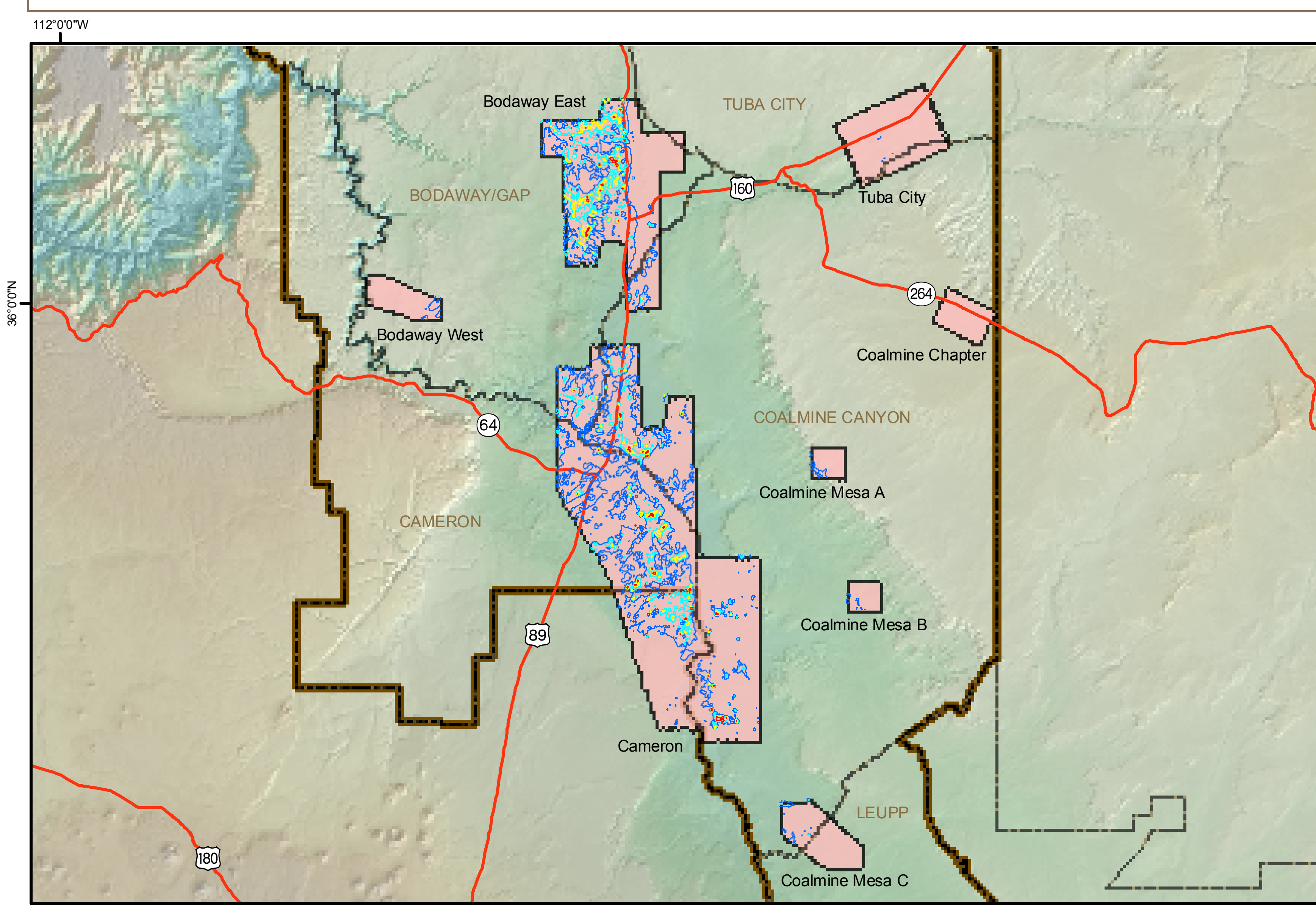
AERIAL RADIATION SURVEY AREAS AND BISMUTH 214 RADIATION CONTOURS

Radiation Contours	Derived contour level Bismuth-214 photo peak (excess counts/sec)	Estimated exposure rate from excess Bismuth-214 (excess μR/hr)
blue	80	3.5
cyan	120	7.4
yellow	250	10.9
orange	800	34.9
purple	1200	52.4

0 15 Miles

Map Scale 1:550,000

Aerial Survey Boundary



AERIAL RADIATION SURVEY AREAS AND GROSS COUNT RADIATION CONTOURS

Radiation Contours	Derived terrestrial exposure rate at 1 meter above ground level. Does not include cosmic contribution. Units in μR/hr.
blue	9
cyan	12
yellow	16
red	24

0 15 Miles

Map Scale 1:550,000

Aerial Survey Boundary

APPENDIX A - GIS DATASETS

DIGITAL ORTHOPHOTO QUARTER QUADRANGLE (DOQQ) IMAGES

While a conventional aerial photograph looks very similar to an orthophotograph (referred to as orthophoto hereafter), it contains image distortions caused by the tilting of the camera and terrain relief (topography). These distortions result in a non-uniform scale across the aerial photo. Distances cannot be accurately measured on an aerial photograph like on a map, and the effect worsens as the terrain increases.

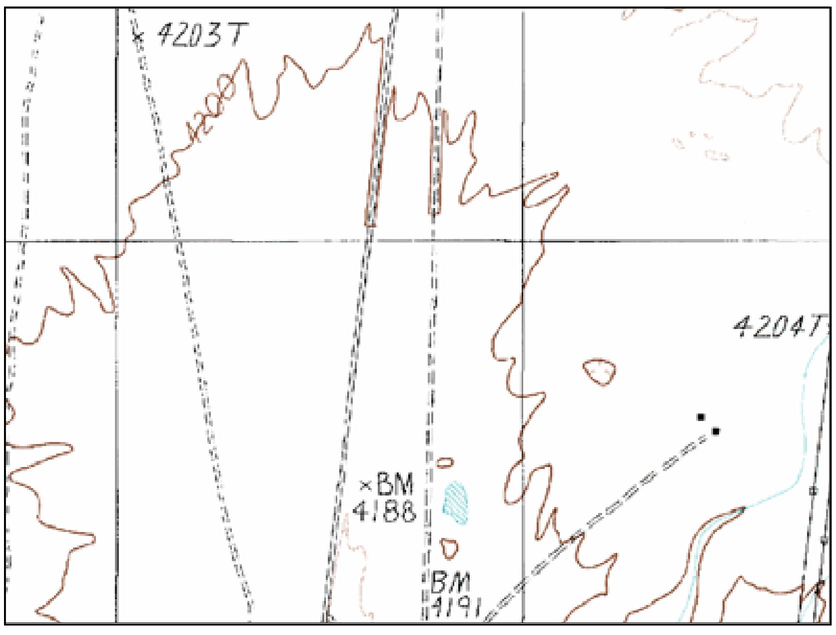
The effects of camera tilt and relief can be removed from aerial photographs by a mathematical process called rectification. Digital orthophotos are computer-generated images of an aerial photograph in which image displacements caused by terrain relief and camera tilts and lens distortions have been removed. The aerial photographs are scanned and processed to create a georeferenced and planimetrically accurate digital image. The production of an orthophoto requires accurate ground control points, camera orientation parameters, and a digital elevation model. The resulting digital orthophoto combines the image characteristics of a photograph with the geometric qualities of a map.

DOQQs produced by the U.S. Geological Survey (USGS) are either gray-scale, natural color, or color-infrared images. Currently, only gray-scale DOQQs are available from the USGS for the Western AUM Region. A DOQQ covers an area measuring 3.75-minutes longitude by 3.75-minutes latitude, or 1/4 of the area covered by a USGS 7.5-minute topographic quadrangle. The names of DOQQs are based on the USGS 7.5-minute quadrangles, followed by a NE, NW, SW, or SE. An index of 7.5-minute topographic quadrangle boundaries and quadrangle names, and the associated DOQQ boundaries are shown on the map figure on the facing page.

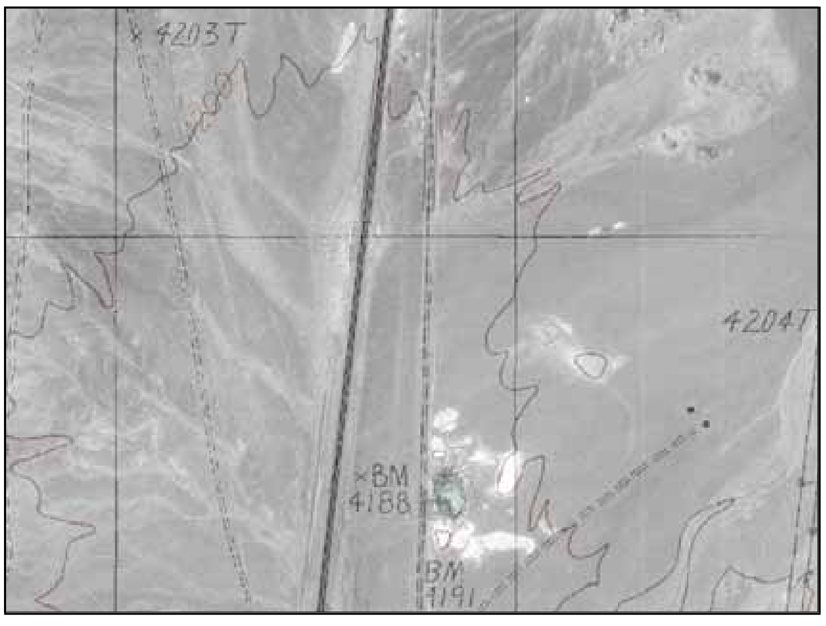
A DOQQ can be used in most any GIS that can manipulate raster images. DOQQs can be used as a cartographic base for displaying other digital spatial data. The accuracy and detail provided by the DOQQ allow users to evaluate their data for accuracy and completeness, make modifications to their data, and even generate new thematic layers. The DOQQs were used extensively in the review and correction of several spatial datasets prepared for this Western AUM Region screening assessment. The DOQQs were also used to generate new data layers, such as the structures mapping.

The DOQQs for the Western AUM Region were generated by the USGS using aerial photographs acquired in 1992, 1997, and 1998. Any construction after this period, such as new roads or buildings, will not be present on the DOQQs.

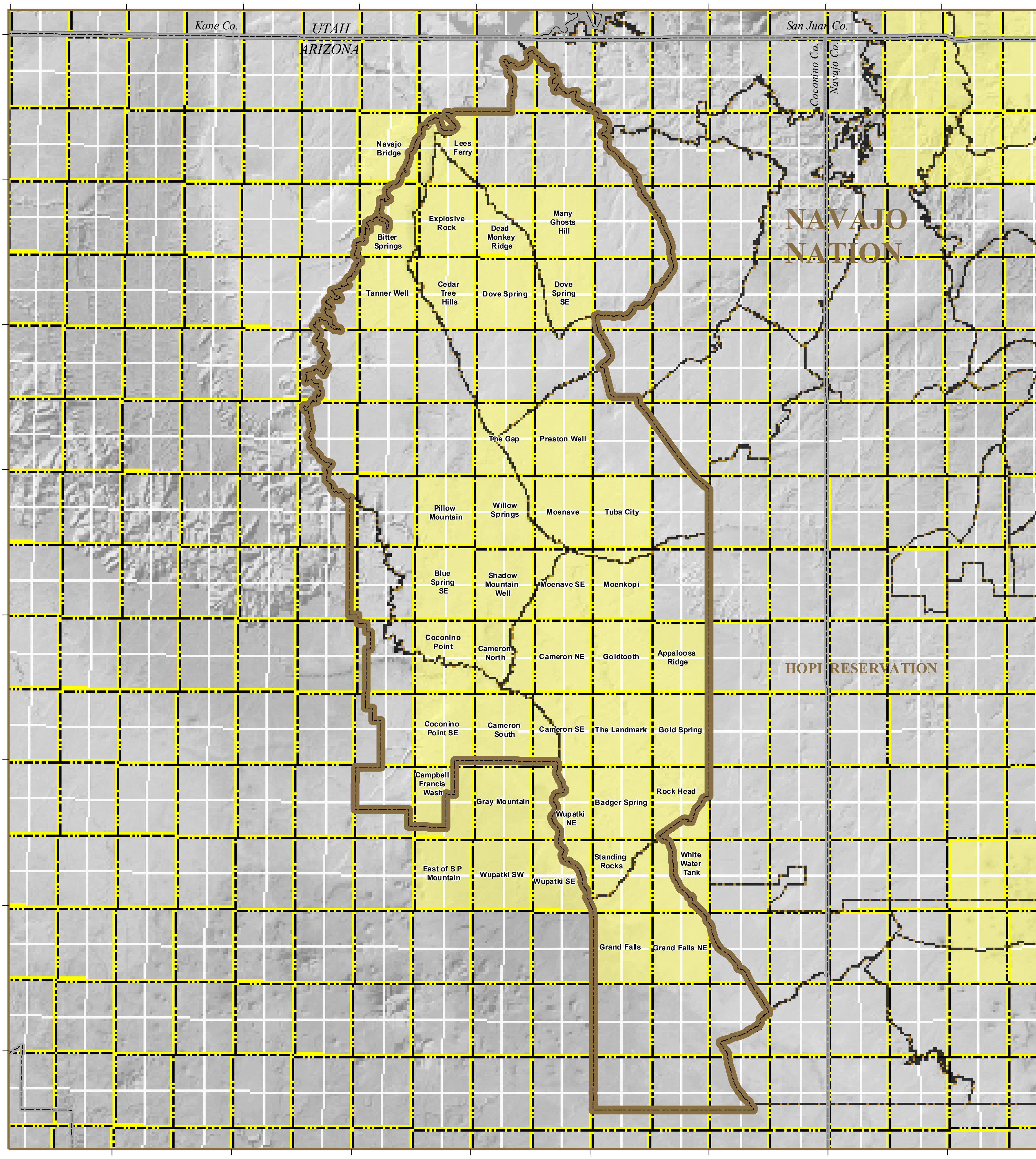
The accuracy and quality of USGS DOQQs meet National Map Accuracy Standards at 1:12,000 scale. DOQQs have a 1-meter ground resolution, and accuracy of +/- 33 feet.

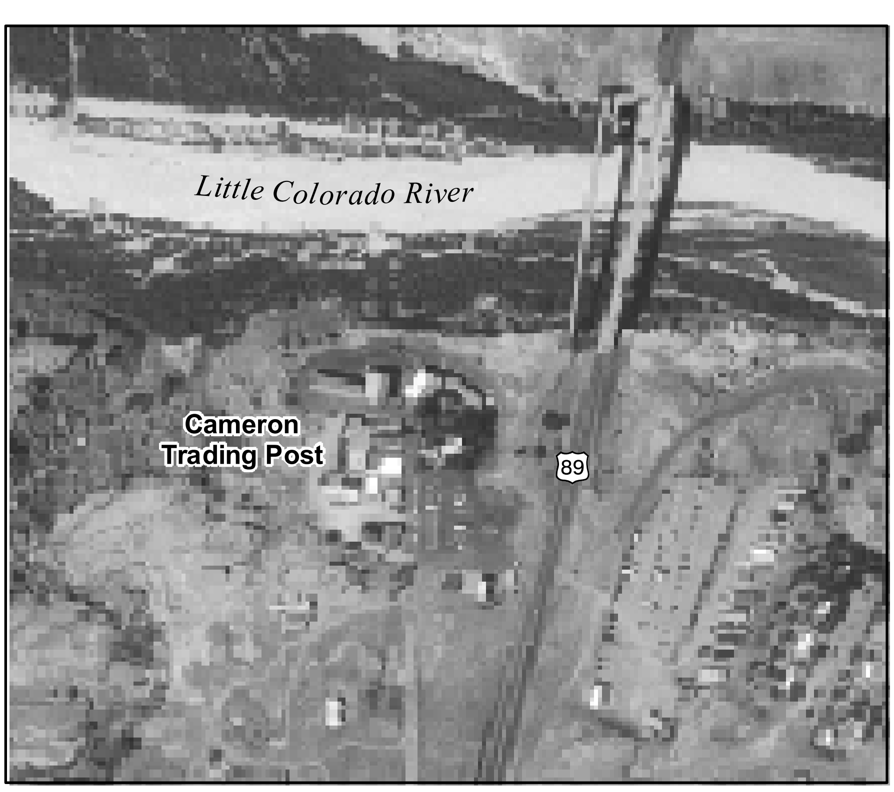


Example of a scanned USGS topographic quadrangle map and a DOQQ of the Jack Daniels Mines in the Cameron North, SE quad in Arizona. These images are presented at a matched scale of nominally 1:24,000 (1" = 2,000 feet) and are shown to illustrate the different information that each can provide.



Example of a scanned USGS topographic quadrangle map overlain on a DOQQ.





Portion of a DOQQ showing the Cameron Trading Post. The Little Colorado River can be seen at the top portion of the image. The insert is shown at a scale of 1:6,000 (1 inch = 500 feet).

ABANDONED URANIUM MINES (AUM) AND THE NAVAJO NATION

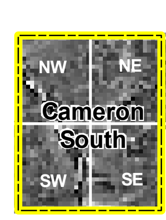
Western AUM Region Screening Assessment Report

DIGITAL ORTHOPHOTO QUARTER QUADRANGLE (DOQQ) INDEX

0 20 Miles

Map Scale 1:800,000

Legend



USGS 7.5-minute topographic quadrangle boundary and quadrangle name for DOQQs used for the Western AUM Region.

Source

Digital Orthophoto Quarter Quadrangles (DOQQ) are generated by the U.S. Geological Survey (USGS).